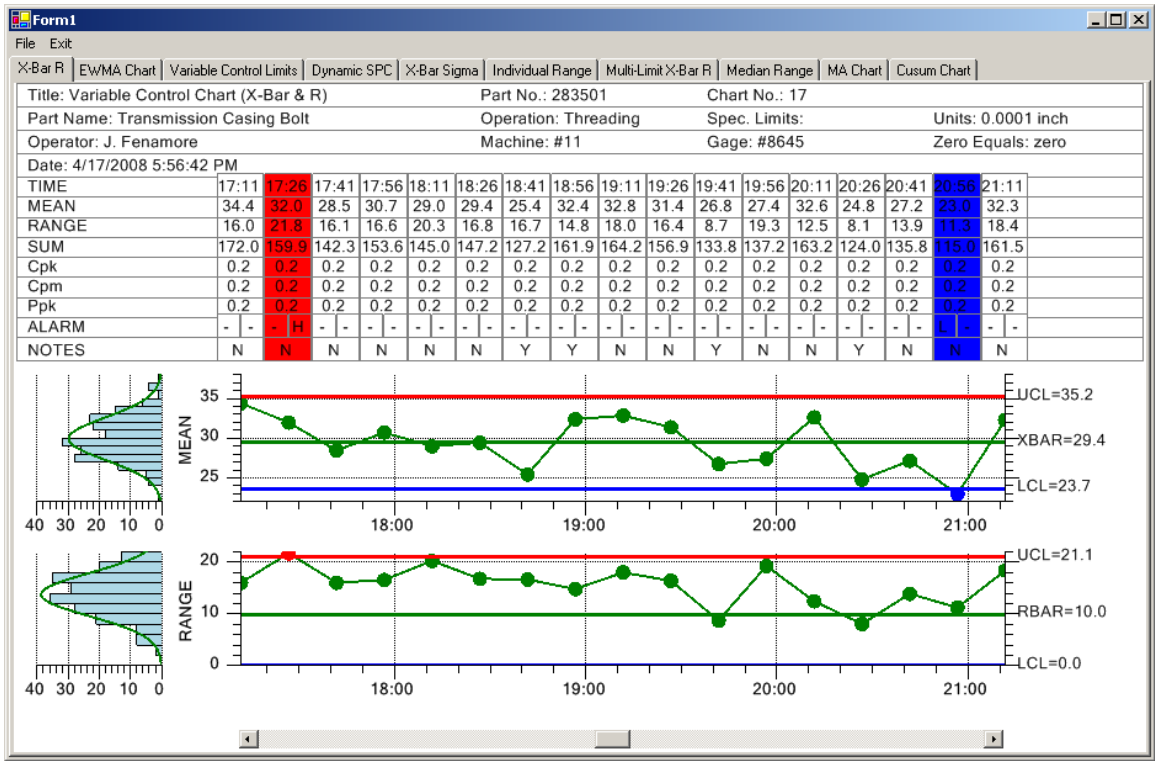
QCSPCChart SPC Control Chart Tools for .Net



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SPC Control Chart Tools for .*Net*

1. Introduction

What's New in Rev. 2.3

All of the new features found in the 2.3 version of QCSPCChart were added to QCChart2D - primarily a new collection of event based charting classes. None of these routines have been used in the QCSPCChart software.

Event-Based Charting

A new set of classes have been added in support of new, event-based plotting system. In event-based plotting, the coordinate system is scaled to the number of event objects. Each event object represents an x-value, and one or more y-values. The x-value can be time based, or numeric based, while the y-values are numeric based. Since an event object can represent one or more y-values for a single x-value, it can be used as the source for simple plot types (simple line plot, simple bar plot, simple scatter plot, simple line marker plot) and group plot types (open-high-low-close plots, candlestick plots, group bars, stacked bars, etc.). Event objects can also store custom data tooltips, and x-axis strings. The most common use for event-based plotting will be for displaying time-based data which is discontinuous: financial markets data for example. In financial markets, the number trading hours in a day may change, and the actual trading days. Weekends, holidays, and unused portions of the day can be excluded from the plot scale, producing continuous plots of discontinuous data. The following classes have been added to the software in support of event-based charting.

- **ChartEvent** - A ChartEvent object stores the position value, the time stamp, y-values, and custom strings associated with the event.
- **EventArray** - A utility array class used to store ChartEvent objects
- **EventAutoScale** – An auto-scale class used by the EventCoordinates class.
- **EventAxis** - Displays an axis based on an EventCoordinates scale
- **EventAxisLabels** – Displays the string labels labeling the tick marks of an EventAxis
- **EventCoordinates** – Event coordinates define a coordinate system based on the the attached Event datasets
- **EventGroupDataset** – A group dataset which uses ChartEvent objects as the source of the data. It is used to feed data into the group plotting routines.
- **EventScale** – An event scale class used to convert between event coordinates and device coordinates.
- **EventSimpleDataset** - A simple dataset which uses ChartEvent objects as the source of the data. It is used to feed data into the simple plotting routines.

What's New in Rev. 2.2

- Three new control charts – Moving Average/Moving Range (MAMR), Moving Average/Moving Sigma (MAMS) and the Number Defects per Million (DPMO). See Chapter 6 (SPC Variable Control Charts) and Chapter 9 (*SPC Attribute Control Charts*).
- Direct support for additional control rule sets – Nelson, AIAG, Juran, Hughes, Gitlow, Westgard, and Duncan, in addition to the WE (Western Electric) and Supplemental Rules. See Chapter 8 (*Named and Custom Control Rule Sets*).
- Create custom sets of control rules, using any rule from any of the standard named control rule sets. See Chapter 8 (*Named and Custom Control Rule Sets*).
- Define custom control rules: based any of our predefined control rule templates See Chapter 8 (*Named and Custom Control Rule Sets*).
- Regionalization – All strings used in the software have been moved to a static class which can be initialized at runtime with country specific strings. See Chapter 11 (*Regionalization for non-USA English Markets*).

New Features found in the 2.1 version of QCSPCChart

Revision 2.1 adds the following new features:

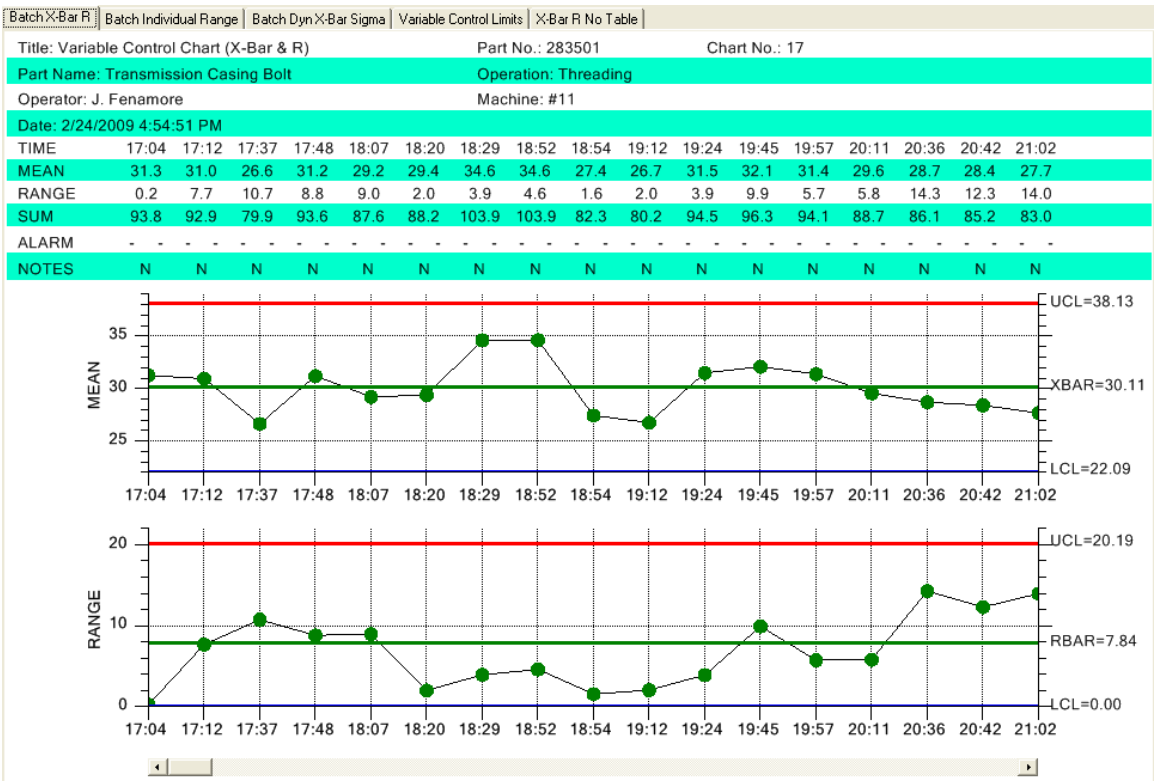
- **Specification Limits** – Unique from control limits. See page 212.
- **Western Electric Trending** (or Supplemental) Rules (Rules 5 – 8). See page 207.
- **Simpler way to set control limits for +-1, 2 and 3 sigma - Add3SigmaControlLimits** – See page 201.
- **Solid area fill between limit lines - ControlLimitLineFillMode** – See page 206.

New Features found in the 2.0 version of QCSPCChart

Revision 2.0 follows Revision 1.7. Most new features associated with revision 2.0 are part of the QCChart2D software, on top of which the QCSPCChart software is built. As far this software goes, only a few featues specific to Revision 2.0 of QCSPCChart have been added. These include:

- The batch control chart templates (SPCBatchVariableControlChart, SPCBatchAttributeControlChart) have new x-axis labeling modes. Label the x-axis tick marks using a batch number (the original and default mode), a time stamp, or a user-defined string.

- The x-axis labels can be rotated 360 degrees.



The time stamp of batch control chart does not have to be does not have to have an equal time spacing between adjacent sample groups.

Revision 2.0 has added many new to QCChart2D. New features include:

- Five new plot types: **BoxWiskerPlot**, **FloatingStackedBarPlot**, **RingChart**, **SimpleVersaPlot** and **GroupVersaPlot**
- Elapsed time scaling to compliment the time/date scaling. Includes a set of classes specifically for elapsed time charts: **ElapsedTimeLabel**, **ElapsedTimeAutoScale**, **ElapsedTimeAxis**, **ElapsedTimeAxisLabels**, **ElapsedTimeCoordinates**, **ElapsedTimeScale**, **ElapsedTimeSimpleDataset** and **ElapsedTimeGroupDataset**.
- Vertical axis scaling for time/date and elapsed time
- A **DatasetViewer** class for the grid-like display of dataset information in a table.
- A **MagniView** class: a new way to zoom data
- A **CoordinateMove** class – used to pan the coordinate system, left, right, up, down.
- Zoom stack processing is now internal to the ChartZoom class

Refer to the QCChart2D manual for information specific to these new features.

Visual Studio 2005 Projects

All of the example program projects have been converted to the Visual Studio 2005 project format. The VS 2005 project format is the oldest project format we expect to support in years moving forward. While it may be possible to use the QCChart2D/QCSPCChart software with VS 2003, or VS 2002, it is not something we support any more. You should assume that as we continue to enhance the software, we will use features not supported under VS 2003/2002. We can still sell you a Revision 1.7 version of the software, with all of the original VS 2003/2002 projects; however it will not include the features described above.

One difference betwee of VS 2005 and VS 2003/2002 is the VS 2005 creation of *partial* classes when using the **Add User Control** wizard. The VS 2005 **Add User Control** wizard now creates two classes, UserControlName.cs and UserControlName.Designer.cs (or UserControlName.vb and UserControlName.Designer.vb), by default. The Designer specific code is now placed in the UserControlName.Designer.vb file. In VS 2003/2002, where a separate UserControlName.Designer.cs file is NOT created, the Designer code was placed in the main UserControlName.cs file, most of which was hidden using the

```
#region Windows Form Designer generated code
```

compiler directive. Many of example programs still use this older style, with the single UserControlName file. The single file structure is forward compatible with the VS 2005 compiler. All of the example programs demonstrating new features in the software use the split UserControlName.cs/UserControlName.Designer.cs file structure. This split structure is NOT backward compaticle with VS 2003/2002.

New Features added to the 1.7 version of QCSPCChart

A large number of new features were added to QCSPCChart in the change from Revision 1.6 to 1.7. These are summarized below:

Eliminated the QCLicense License Fle

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New SPC Chart Types and Features

- Three new charts have been added to the software: **EWMA** (Exponentially Weighted Moving Average), **MA** (Moving Average), and **CuSum** (Cumulative Sum) charts.

- Three variants of existing charts have been adapted to support variable subgroup sample sizes: X-Bar Sigma, p-Chart (Fraction or Percent of Defective Parts) and u-Chart (Number of Defects per Unit).

- The FrequencyHistogramChart now includes optional limit lines, and an optional fit and overlay of a normal curve to the frequency data.

New Alarm Features

- There is a new status line in the table section that gives a direct indication of whether or not the corresponding process variable is in, or out of, alarm. The status line has a tooltip, so if you click on an alarm, a pop-up box will show you details.

- Optionally, the entire column associated with a sample interval can be color highlighted to indicate an alarm condition.

- Alarm details can be automatically logged to the notes log.

- The symbol used to plot a process variable point in the primary and secondary charts can be made to change color in the event of an alarm.

DesignerSerializationVisibility

We have long found the VS IDE habit of including long initialization lists for the **ChartView** and **SPCBaseChart** properties, when a **ChartView** derived **UserControl** is added to a Form, annoying. We found it was very easy to initialize properties in a **ChartView** or **SPCBaseChart** subclass, only to have them over-ridden in hidden InitializeComponent code. So we added the:

```
DesignerSerializationVisibility(DesignerSerializationVisibility.Hidden)]
```

compiler flag in front of all **ChartView** and **SPCBaseChart** properties to force the VS IDE to ignore them.

Tutorials

Chapter 12 is a tutorial that describes how to get started with the **SPC Control Chart Tools for .Net** charting software. Chapter 13 is a tutorial that describes how to use the software to create charts for web pages.

Customer Support

Use our forums at http://www.quinn-curtis.com/ForumFrame.htm for customer support. Please, do not post questions on the forum unless you are familiar with this manual and have run the examples programs provided. We try to answer most questions by referring to the manual, or to existing example programs. We will always attempt to answer any question that you may post, but be prepared that we may ask you to create, and send to us, a simple example program. The program should reproduce the problem with no, or minimal interaction, from the user. You should strip out of any code not directly associated with reproducing the problem. You can either your own example or a modified version of one of our own examples.

SPC Control Chart Tools for .*Net* Background

In a competitive world environment, where there are many vendors selling products and services that *appear* to be the same, **quality**, both real and perceived, is often the critical factor determining which product wins in the marketplace. Products that have a reputation for higher quality command a premium, resulting in greater market share and profit margins for the manufacturer. Low quality products not only take a big margin hit at the time of sale, but also taint the manufacturer with a reputation that will hurt future sales, regardless of the quality of future products. Users have a short memory. A company's quality reputation is only as good as the quality of its most recent product.

The measurement, control and gradual improvement of quality is the goal of all quality systems, no matter what the name. Some of the more common systems are known as **SCC** (Statistical Quality Control) **Quality Engineering**, **Six-Sigma**, **TQM** (Total Quality Management), **TQC** (Total Quality Control), **TQA** (Total Quality Assurance) and **CWQC** (Company- Wide Quality Control). These systems work on the principle that management must integrate quality into the basic structure of the company, and not relegate it to a Quality Control group within the company. Historically, most of the innovations in quality systems took place in the 20th century, with pioneering work carried out by Frederick W. Taylor (Principles of Scientific Management), Henry Ford (Ford Motor), W. A. Shewhart (Bell Labs), W. E. Deming (Department of Agriculture, War department, Census Bureau), Dr. Joseph M. Juran (Bell Labs), and Dr. Armand V. Feigenbaum among others. Most quality control engineers are familiar with the story of how the statistical quality control pioneer, W. E. Deming, frustrated that US manufactures only gave lip service to quality, took the quality system he developed to Japan, where it was embraced with almost religious zeal. Japanese industry considers Deming a national hero, where his quality system played a major role in the postwar expansion of the Japanese economy. Twenty to thirty years after Japan embraced his methods, Deming found a new audience for his ideas at US companies that wanted to learn *Japanese* methods of quality control.

All quality systems use Statistical Process Control (**SPC**) to one degree or another. SPC is a family of statistical techniques used to track and adjust the manufacturing process in order to produce gradual improvements in quality. While it is based on sophisticated mathematical analysis involving sampling theory, probability distributions, and statistical

inferences, SPC results can usually be summarized using simple charts that even management can understand. SPC charts can show how product quality varies with respect to critical factors that include things like batch number, time of day, work shift personal, production machine, and input materials. These charts have odd names like X-Bar R, Median Range, Individual Range, Fraction Number Non-Conforming, and NP. The charts plot some critical process variable that is a measurement of product quality and compares it to predetermined limits that signify whether or not the process is working properly.

Initially, quality control engineers create all SPC charts by hand. Data points were painstakingly gathered, massaged, summed, averaged and plotted by hand on graph paper. It is still done this way in many cases. Often times it is done by the same factory floor personal who control the process being measured, allowing them to "close the loop" as quickly as possible, correcting potential problems in the process before it goes out of control. Just as important, SPC charts tell the operator when to leave the process alone. Trying to micro-adjust a process, when the process is just exhibiting normal random fluctuations in quality, will often drive the process out of control faster than leaving it alone.

The modern tendency is to automate as much of the SPC chart creation process as possible. Electronic measuring devices can often measure quality in real-time, as items are coming off the line. Usually some form of sampling will be used, where one of every N items is measured. The sampled values form the raw the data used in the SPC chart making process. The values can be entered by hand into a SPC chart making program, or they can be entered directly from a file or database connection, removing the potential for transcription errors. The program displays the sampled data in a SPC chart and/table where the operator or quality engineer can make a judgment about whether or not the process is operating in or out of control.

Usually the SPC engineer tasked with automating an existing SPC charting application has to make a decision about the amount of programming he wants to do. Does he purchase an application package that implements standard SPC charts and then go about defining the charts using some sort of menu driven interface or wizard. This is probably the most expensive in terms of up front costs, and the least flexible, but the cheapest in development costs since a programmer does not have to get involved creating the displays. Another choice is to use a general purpose spreadsheet package with charting capability to record, calculate, and display the charts. This is probably a good choice if your charting needs are simple, and you are prepared to write complicated formulas as spreadsheet entries, and your data input is not automated. Another choice is writing the software from scratch, using a charting toolkit like our ***QCChart2D*** software as the base, and creating custom SPC charts using the primitives in the toolkit. This is cheaper up front, but may be expensive in terms of development costs. Often times the third option is the only one available because the end-user has some unique requirement that the pre-packaged software can't handle, hence everything needs to programmed from scratch.

Quinn-Curtis SPC (Statistical Process Control) Software

We have created a library of SPC routines that represents an intermediate solution. Our SPC software still requires an intermediate level programmer, but it does not require advanced knowledge of SPC or of charting. Built on top our ***QCChart2D,*** it implements templates and support classes for the following SPC charts and control limit calculations.

Variable Control Charts Templates

- Fixed sample size subgroup control charts
  - X-Bar R – (Mean and Range Chart)
  - X-Bar Sigma (Mean and Sigma Chart)
  - Median and Range (Median and Range Chart)
  - X-R (Individual Range Chart)
  - EWMA (Exponentially Weighted Moving Average Chart)
  - MA (Moving Average Chart)
  - MAMR (Moving Average / Moving Range Chart)
  - MAMS (Moving Average / Moving Sigma Chart)
  - CuSum (Tabular Cumulative Sum Chart)
- Variable sample size subgroup control charts
  - X-Bar Sigma (Mean and Sigma Chart)

Attribute Control Charts Templates

- Fixed sample size subgroup control charts
  - p Chart (Fraction or Percent of Defective Parts)
  - np Chart (Number of Defective Parts)
  - c-Chart (Number of Defects)
  - u-Chart (Number of Defects per Unit)
  - Number Defects per Million (DPMO)
- Variable sample size subgroup control charts
  - p Chart (Fraction or Percent of Defective Parts)
  - u-Chart (Number of Defects per Unit)

Analysis Chart Templates

- Frequency Histograms
- Probability Charts
- Pareto Charts

SPC Support Calculations

- Array statistics (sum, mean, median, range, standard deviation, variance, sorting)

SPC Control Limit Calculations

- High and low limit control calculations for X-Bar R, X-Bar Sigma, Median and Range, X-R, p, np, c and u charts

SPC Process Capability Calculations

- Variable Control Charts include Cp, Cpl, Cpu, Cpk, Cpm, Pp, Ppl, Ppu, and Ppk process capability statistics

SPC Control Named Rule Sets

Western Electric (WECO) Runtime and Supplemental Rules
Nelson
AIAG
Juran
Hughes
Gitlow
Westgard
Duncan

The **SPC Control Chart Tools for *.Net*** is a family of templates that integrate the **QCChart2D** charting software with tables, data structures and specialized rendering routines used for the static and dynamic display of SPC charts. The SPC chart templates are pre-programmed classes that create, manage and display the graphs and tables corresponding to major SPC control chart types. Each template can be further customized using method and properties. The programmers can customize the plot objects created in the template, allowing tremendous flexibility in the look of the SPC charts.

Like the **QCChart2D** software, the **SPC Control Chart Tools for** .Net uses the graphics features found in the Microsoft .Net API. These include:

- Arbitrary line thickness and line styles for all lines.
- Printer and image output support
- Font support for a large number of fonts, using a variety of font styles, size and rotation attributes.
- Imaging support for a large number of image formats

SPC Control Chart Tools for *.Net* Dependencies

The **SPC Control Chart Tools for *.Net*** class library builds on the **QCChart2D** software package. It uses the classes found in that software and standard classes that ship with the Microsoft .Net API. No other software is required.

Directory Structure of QCSPCChart for *.Net*

The **SPC Control Chart Tools for** .Net class library uses the standard directory structure also used by the **QCChart2D** and **QCRTGraphics** software. It adds the **QCSPCChart** directory structure under the Quinn-Curtis\DotNet folder. For a list of the folders specific to **QCChart2D**, see the manual for **QCChart2D**, QCChart2DNetManual.pdf.

Drive:

Quinn-Curtis\ - Root directory

DotNet\ - Quinn-Curtis .Net based products directory

Docs\ - Quinn-Curtis .Net related documentation directory

Lib\ - Quinn-Curtis .Net related compiled libraries and components directory

QCChart2D\ - QCChart2D examples for C# and VB – This directory contains many example programs for C# and VB specific to the QCChart2D charting software, but not specific to the QCSPCChart software

QCSPCChart\ - QCSPCChart examples for C# and VB

Visual CSharp\ - C# specific directory

QCSPCChartClassLib\ - contains the source code to the QCSPCChartNet.dll library (installed only if the source code has been purchased)

Examples\ - C# examples directory

FrequencyHistogram – a simple frequency histogram example using the **FrequencyHistogramChart** class

BatchAttributeControlCharts - a collection of batch attribute control charts, including n, np, c, and u charts using the **SPCBatchAttributeControlChart** class.

BatchVariableControlCharts - a collection of batch variable control charts, including X-Bar R, X-Bar Sigma, Median Range, and X-R charts using the **SPCBatchVariableControlChart** class.

TimeAttributeControlCharts - a collection of time attribute control charts, including n, np, c, and u charts using the **SPCTimeAttributeControlChart** class.

TimeVariableControlCharts BatchVariableControlCharts - a collection of time variable control charts, including X-Bar R, X-Bar Sigma, Median Range, and X-R charts using the **SPCTimeVariableControlChart** class.

MiscTimeBasedControlCharts - a collection of time variable control charts, including EWMA, MA and CuSum charts using the **SPCTimeVariableControlChart** class.

MiscBatchBasedControlCharts - a collection of batch variable control charts, including EWMA, MA and CuSum charts using the **SPCTimeVariableControlChart** class.

RulesRulesRules - a collection of control charts demonstrating the the use of named (WECO, Nelson, AIAG, Juran, Hughes, Duncan, Westgard, and Gitlow) and custom rule sets.

ProbabilityPlot - a probability chart using the **ProbabilityChart** class.

ParetoDiagram - a Pareto diagram chart using the **ParetoChart** class.

SPCApplication1 – A simple X-Bar R example program, using **SPCTimeVariableControlChart**, used in the tutorial.

WERulesVariableControlCharts - a collection of using the WE rules with **SPCTimeVariableControlChart** charts, including X-Bar R, X-Bar Sigma, Median Range, and X-R

VariableSampleSizeControlCharts - a collection of the variable control (X-Bar Sigma), and attribute control (p- and u-charts) that support variable sample subgroup sizes.

WindowsControlLibrary1 – Create a **QCSPCChart ChartView** derived window that can be embedded in Windows Internet Explorer

Visual Basic\ - VB specific code

Examples\ - VB examples

Same as the C# examples above

(*** Critical Note ***) Running the Example Programs

The example programs for **SPC Control Chart Tools for .Net** software are supplied in complete source. In order to save space, they have not been pre-compiled which means that many of the intermediate object files needed to view the main form are not present. This means that **ChartView** derived control will not be visible on the main Form if you

attempt to view the main form before the project has been compiled. The default state for all of the example projects should be the Start Page. Before you do view any other file or form, do a build of the project. This will cause the intermediate files to be built. If you attempt to view the main Form before building the project, Visual Studio sometimes decides that the **ChartView** control placed on the main form does not exist and deletes it from the project.

There are two versions of the for **SPC Control Chart Tools for .*Net*** class library: the 30-day trial versions, and the developer version. Each version has different characteristics that are summarized below:

30-Day Trial Version

The trial version of **SPC Control Chart Tools for .*Net*** is downloaded in a file named Trial_QCSPCChartR20x. The 30-day trial version stops working 30 days after the initial download. The trial version includes a version message in the upper left corner of the graph window that cannot be removed.

Developer Version

The developer version of **SPC Control Chart Tools for .*Net*** is downloaded in a file with a name similar to NETSPCDEV1UR2x2x561x1.zip The developer version does not time out and you can use it to create application programs that you can distribute royalty free. You can download free updates for a period of 2-years. When you placed your order, you were e-mailed download link(s) that will download the software. Those download links will remain active for at least 2 years and should be used to download current versions of the software. After 2 years you may have to purchase an upgrade to continue to download current versions of the software

Chapter Summary

The remaining chapters of this book discuss the **SPC Control Chart Tools for .*Net*** package designed to run on any hardware that has a .Net runtime installed on it.

Chapter 2 presents a summary of the standard SPC control charts that can be created using the software.

Chapter 3 presents the overall class architecture of the **SPC Control Chart Tools for .*Net*** and summarizes all of the classes found in the software.

Chapter 4 summarizes the important **QCChart2D** classes that you must be familiar with in order to customize advanced features of the **SPC Control Chart Tools for *.Net*** software.

Chapter 5 describes the classes that hold SPC control chart data and control limit alarms.

Chapter 6 describes how the **SPCTimeVariableControlChart** and **SPCBatchVariableControlChart** classes create common variable control charts: X-Bar R, Median and Range, X-Bar Sigma, X-R, EWMA, MA and CuSum charts**.**

Chapter 7 describes how the **SPCTimeAttributeControlChart** and **SPCBatchAttributeControlChart** classes create common attribute control charts: p-, np-, c- and u-charts.

Chapter 8 describes how to implement the named control rules (WECO, Nelson, AIAG, Juran, Hughes, Gitlow, Westgard, and Duncan) control rules. It also describes how to implement custom rules sets, and how to define your own rules using our standardized templates.

Chapter 9 describes how the **FrequencyHistogramChart**, **ParetoChart** and **ProbabilityChart** classes create ancillary SPC charts.

Chapter 10 describes how to print the SPC charts, and save them to image files.

Chapter 11 describes how to regionalize the software for non-USA English markets.

Chapter 12 is a tutorial that describes how to use **SPC Control Chart Tools for .Net** to create Windows applications using Visual Studio .Net, Visual C# and Visual Basic.

Chapter 13 is a tutorial that describes how to use **SPC Control Chart Tools for .Net** to create SPC charts for web pages.

2. Standard SPC Control Charts

There are many different types SPC control charts. Normally they fall into one of two major classifications: *Variable Control Charts*, and *Attribute Control Charts*. Within each classification, there are many sub variants. Often times the same SPC chart type has two or even three different names, depending on the software package and/or the industry the chart is used in. We have provided templates for the following SPC control charts:

Variable Control Charts

- Fixed sample size subgroup control charts
  - X-Bar R – (Mean and Range Chart)
  - X-Bar Sigma (Mean and Sigma Chart)
  - Median and Range (Median and Range Chart)
  - X-R (Individual Range Chart)
  - EWMA (Exponentially Weighted Moving Average Chart)
  - MA (Moving Average Chart)
  - MAMR (Moving Average / Moving Range Chart)
  - MAMS (Moving Average / Moving Sigma Chart)
  - CuSum (Tabular Cumulative Sum Chart)
- Variable sample size subgroup control charts
  - X-Bar Sigma (Mean and Sigma Chart)

Attribute Control Charts

- Fixed sample size subgroup control charts
  - p Chart (Fraction or Percent of Defective Parts)
  - np Chart (Number of Defective Parts)
  - c-Chart (Number of Defects)
  - u-Chart (Number of Defects per Unit)
  - Number Defects per Million (DPMO)
- Variable sample size subgroup control charts
  - p Chart (Fraction or Percent of Defective Parts)
  - u-Chart (Number of Defects per Unit)

Time-Based and Batch-Based SPC Charts

We have further categorized *Variable Control charts* and *Attribute Control Charts* as either time- or batch- based. While you may not find this distinction in SPC textbooks (we didn't), it makes sense to us as charting experts. Quality engineers use time-based SPC charts when data is collected using a subgroup interval corresponding to a specific time interval. They use batch-based SPC charts when the data subgroup interval is a

sequential batch number that does not correspond to a uniform time interval. The major difference in these two types of SPC charts is the display of the x-axis. Variable control charts that sample using a uniform time interval will generally use a time-based x-axis, with time/date axis labels. Variable control charts that sample based on batches will generally use a numeric-based x-axis, with numeric axis labels.

Note: Starting with Revision 2.0, batch control charts can label the x-axis using one of three options: numeric labeling (the original and default mode), time stamp labeling, and user defined string labeling. Since this affects batch control charts, time stamps to not have to be equally spaced, or even sequential.

SPC Analysis Charts

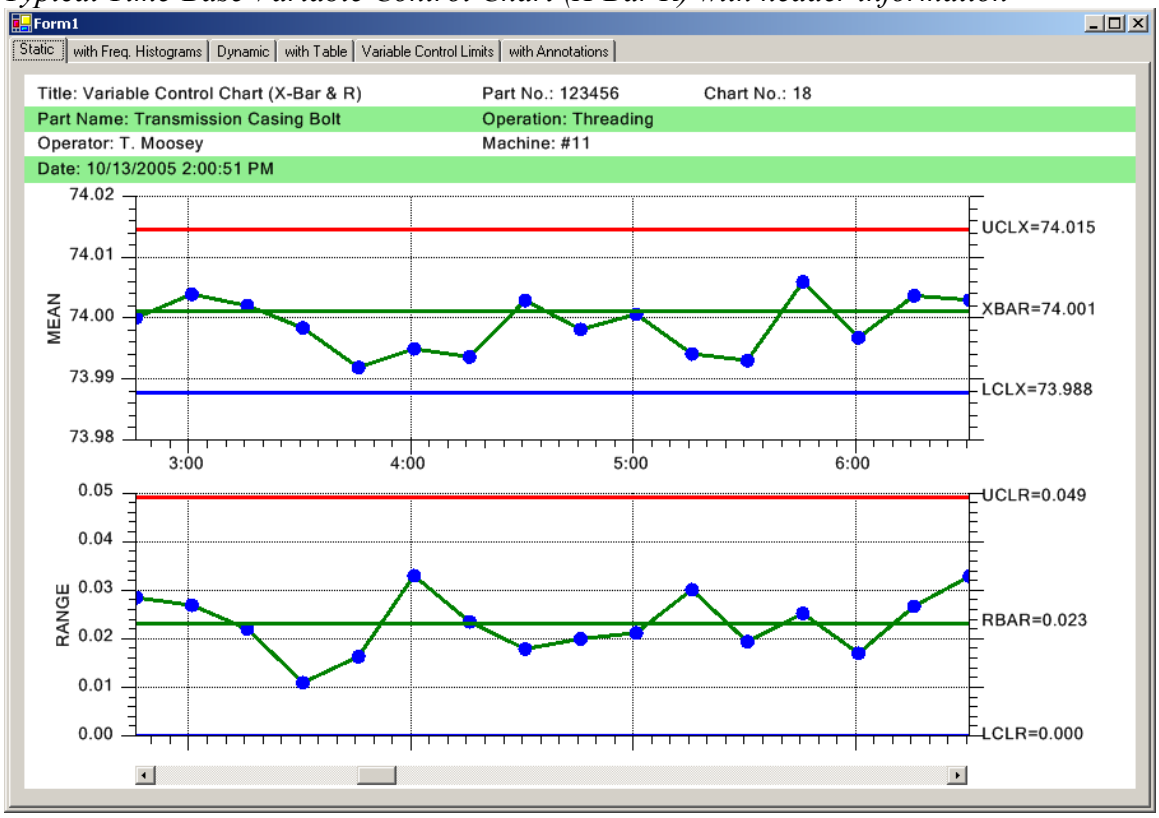
Quality engineers use other, specialized, charts in the analysis of SPC data. We have added chart classes that implement the following SPC analysis charts:

- Frequency Histograms
- Probability Charts
- Pareto Charts

Variable Control Charts

Variable Control Charts are for use with sampled quality data that can be assigned a specific numeric value, other than just 0 or 1. This might include, but is not limited to, the measurement of a critical dimension (height, length, width, radius, etc.), the weight a specific component, or the measurement of an important voltage. Common types of *Variable Control Charts* include X-Bar R (Mean and Range), X-Bar Sigma, Median and Range, X-R (Individual Range), EWMA, MA, MAMR (Moving Average/Moving Range), MAMS (Moving Average/Moving Sigma) and CuSum charts.

Typical Time-Base Variable Control Chart (X-Bar R) with header information



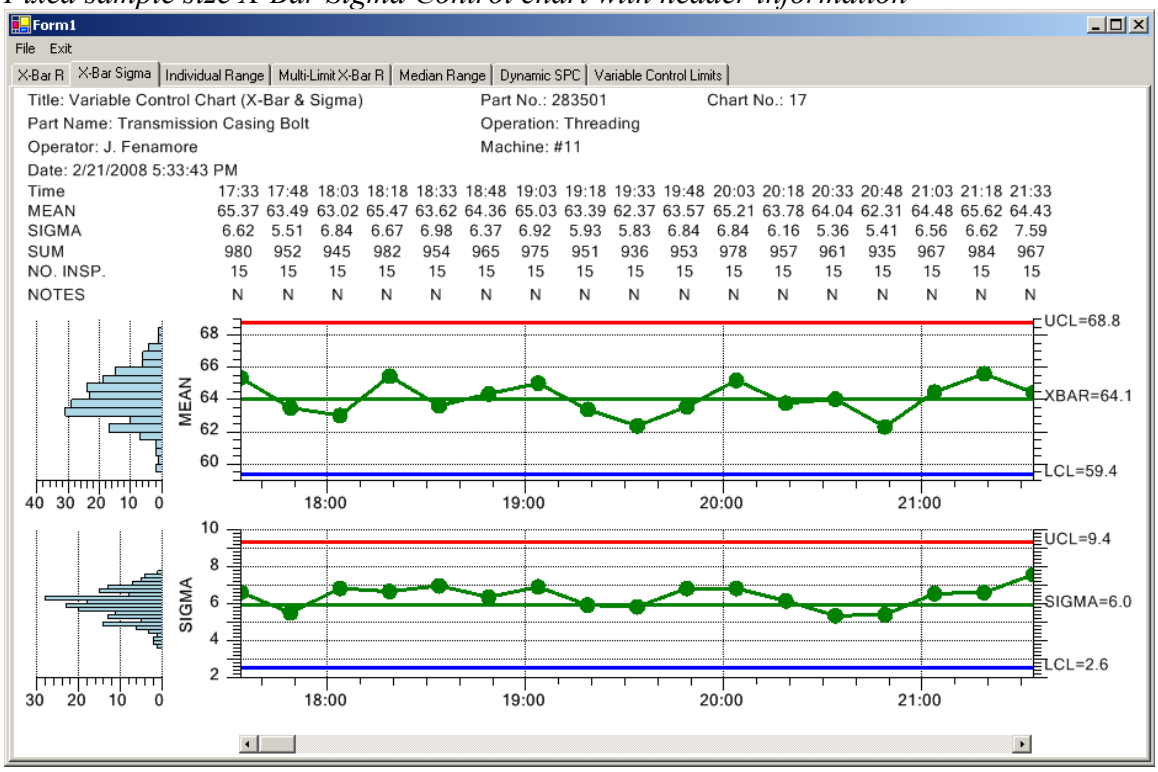
X-Bar R Chart – Also known as the Mean (or Average) and Range Chart

The X-Bar R chart monitors the trend of a critical process variable over time using a statistical sampling method that results in a subgroup of values at each subgroup interval. The X-Bar part of the chart plots the mean of each sample subgroup and the Range part of the chart monitors the difference between the minimum and maximum value in the subgroup.

X-Bar Sigma Chart

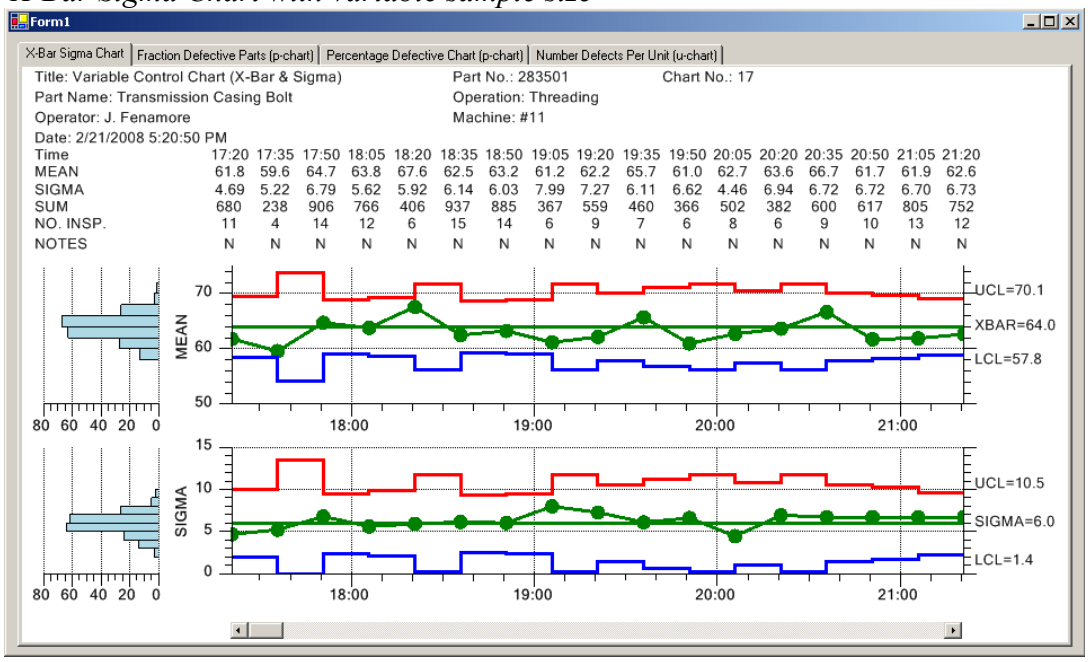
Very similar to the X-Bar R Chart, the X-Bar Sigma chart replaces the Range plot with a Sigma plot based on the standard deviation of the measured values within each subgroup. This is a more accurate way of establishing control limits if the sample size of the subgroup is moderately large (> 10). Though computationally more complicated, the use of a computer makes this a non-issue.

Fixed sample size X-Bar Sigma Control chart with header information



The X-Bar Sigma chart can also be used if the sample subgroup size varies from sampling interval to sampling interval. In this case, the control chart high and low limits vary from sample interval to sample interval, depending on the number of samples in the associated sample subgroup. A low number of samples in the sample subgroup make the band between the high and low limits wider than if a higher number of samples are available. The X-Bar Sigma chart is the only variable control chart that can be used with a variable sample size.

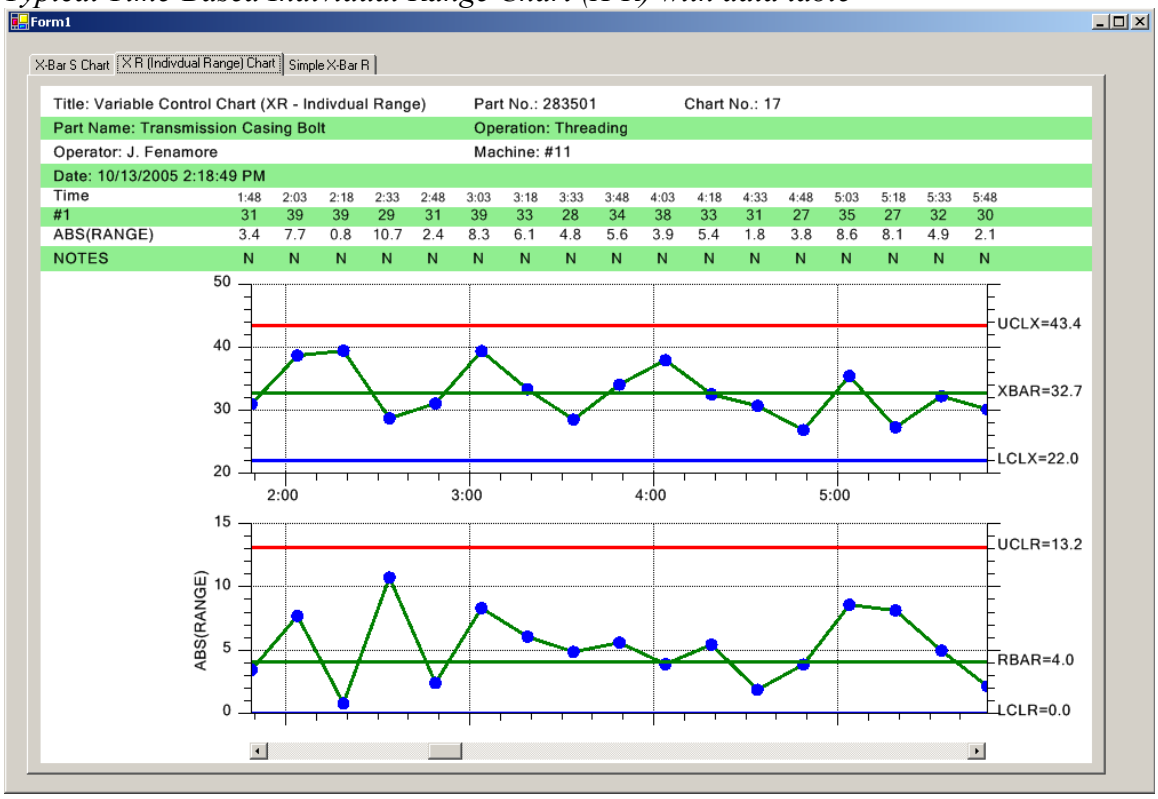
X-Bar Sigma Chart with variable sample size



Median Range – Also known as the Median and Range Chart

Very similar to the X-Bar R Chart, Median Range chart replaces the Mean plot with a Median plot representing the median of the measured values within each subgroup. The Median Range chart requires that the process be well behaved, where the variation in measured variables are (1) known to be distributed normally, (2) are not very often disturbed by assignable causes, and (3) are easily adjusted.

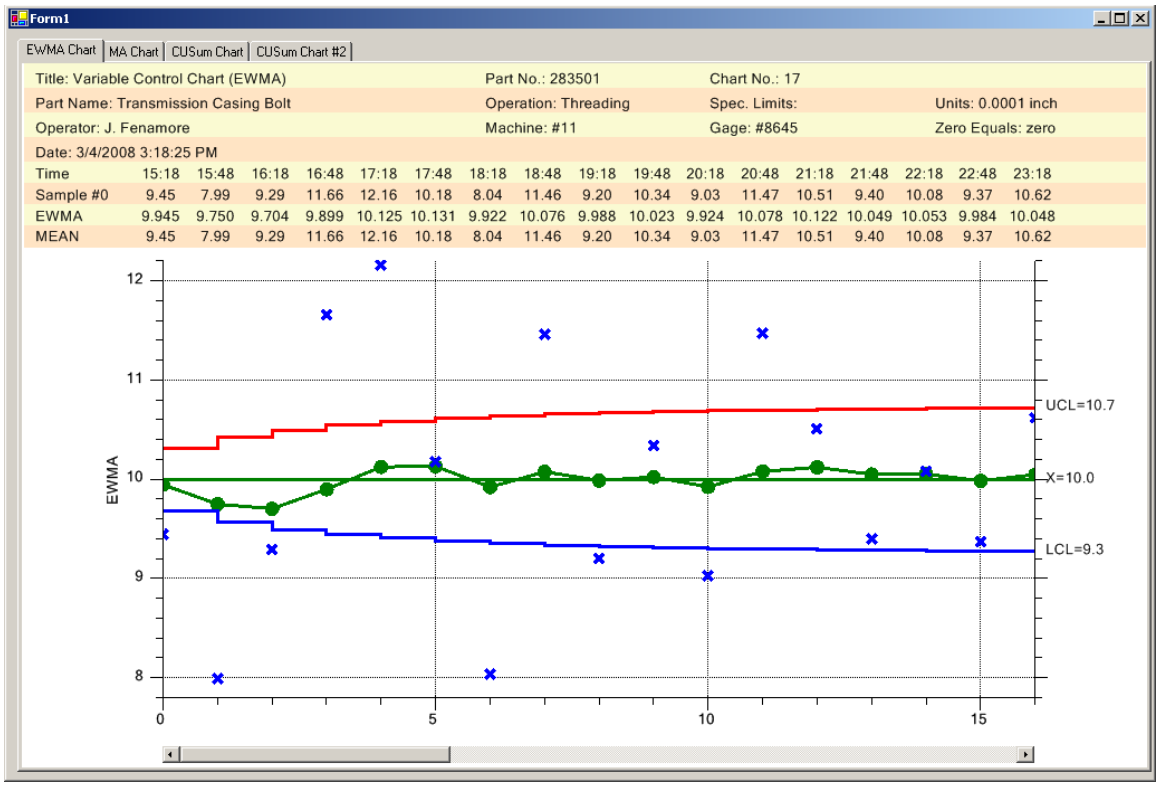
Typical Time-Based Individual Range Chart (X-R) with data table



Individual Range Chart – Also known as the X-R Chart

The Individual Range Chart is used when the sample size for a subgroup is 1. This happens frequently when the inspection and collection of data for quality control purposes is automated and 100% of the units manufactured are analyzed. It also happens when the production rate is low and it is inconvenient to have sample sizes other than 1. The X part of the control chart plots the actual sampled value (not a mean or median) for each unit and the R part of the control chart plots a moving range, calculated using the current value of sampled value minus the previous value.

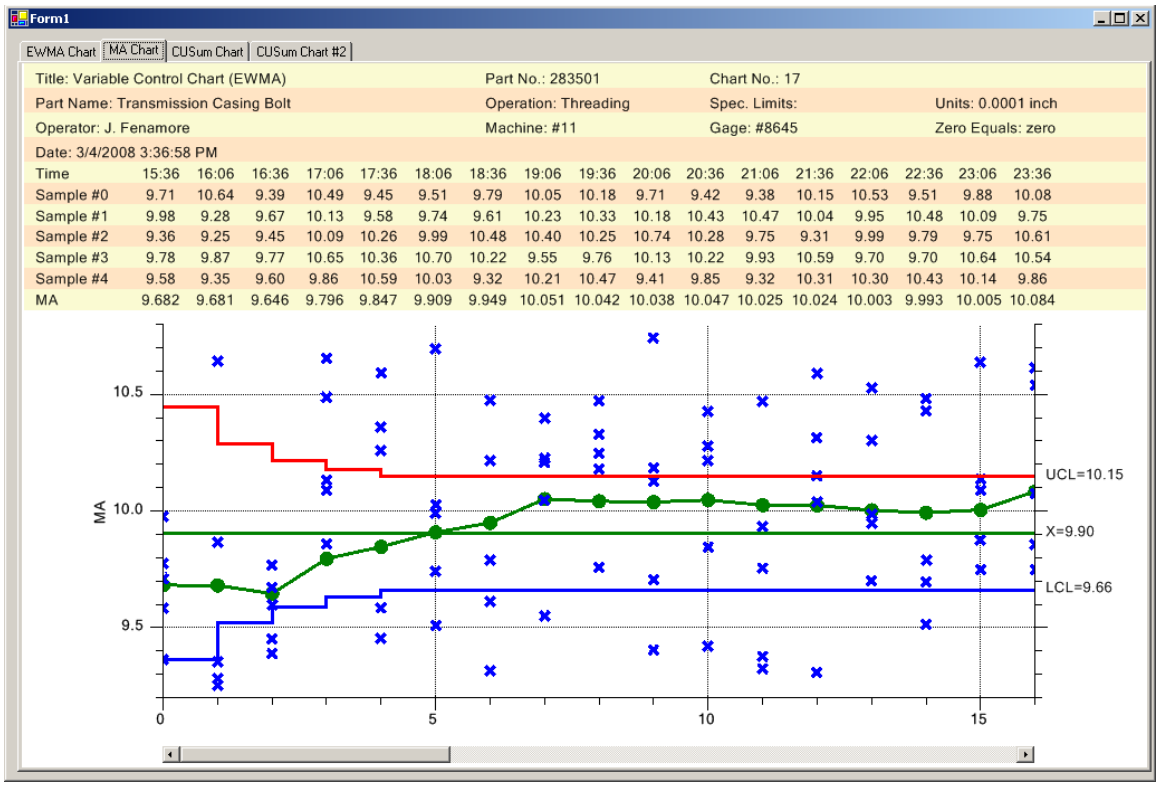
Typical EWMA Chart using Batch Sampling



EWMA Chart – Exponentially Weighted Moving Average

The EWMA chart is an alternative to the preceding Shewhart type control charts (X-Bar R and I-R charts in particular) and is most useful for detecting small shifts in the process mean. It uses a weighted moving average of previous values to "smooth" the incoming data, minimizing the affect of random noise on the process. It weights the current and most recent values more heavily than older values, allowing the control line to react faster than a simple MA (Moving Average) plot to changes in the process. Like the Shewhart charts, if the EWMA value exceeds the calculated control limits, the process is considered out of control. While it is usually used where the process uses 100% inspection and the sample subgroup size is 1 (same is the I-R chart), it can also be used when sample subgroup sizes are greater than one.

MA (Moving Average) Chart with Sample Values Plotted

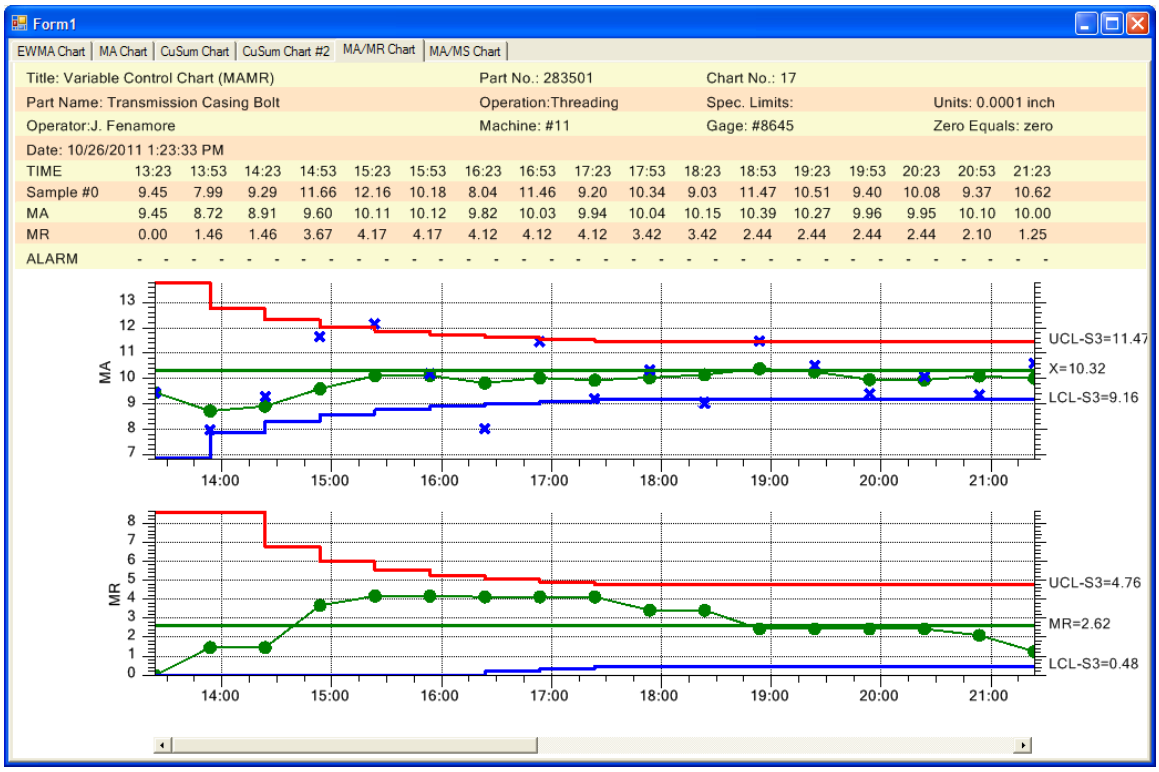


MA Chart – Moving Average

The MA chart is another alternative to the preceding Shewhart type control charts (X-Bar R and I-R charts in particular) and is most useful for detecting small shifts in the process mean. It uses a moving average, where the previous (N-1) sample values of the process variable are averaged together along with the process value to produce the current chart value. This helps to "smooth" the incoming data, minimizing the affect of random noise on the process. Unlike the EWMA chart, the MA chart weights the current and previous (N-1) values equally in the average. While the MA chart can often detect small changes in the process mean faster than the Shewhart chart types, it is generally considered inferior to the EWMA chart. Like the Shewhart charts, if the MA value exceeds the calculated control limits, the process is considered out of control.

MAMR Chart – Moving Average / Moving Range

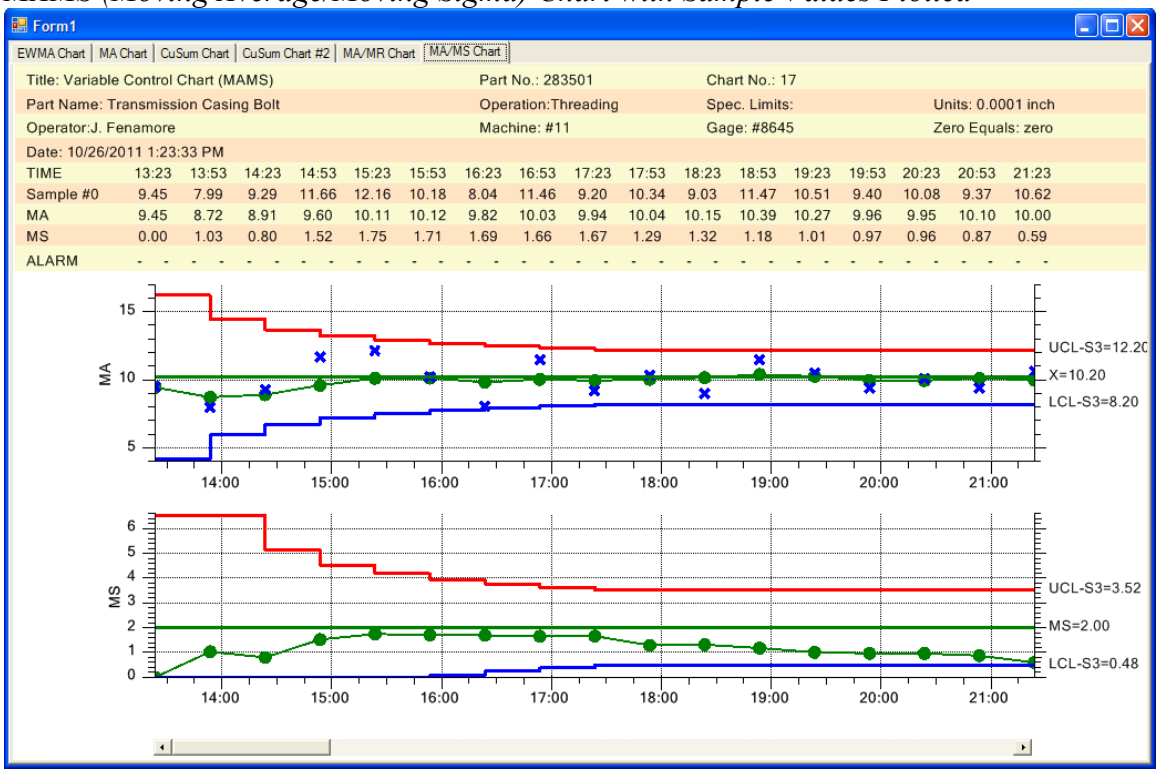
MAMR (Moving Average/Moving Range) Chart with Sample Values Plotted



The MAMR chart combines our Moving Average chart with a Moving Range chart. The Moving Average chart is primary (topmost) chart, and the Moving Range chart is the secondary (bottom) chart. It uses a single sample/subgroup, same as our standard [Individual-Range], [Moving Average], [EWMA], and [Moving Average] charts. When calculating the Moving Range, it windows the same data values used in the Moving Average calculation. Note that the limits are variable (wider) at the beginning, taking into account the fewer samples in the start up of any type of SPC chart which uses a sliding window in the calculation of moving average and moving range statistics.

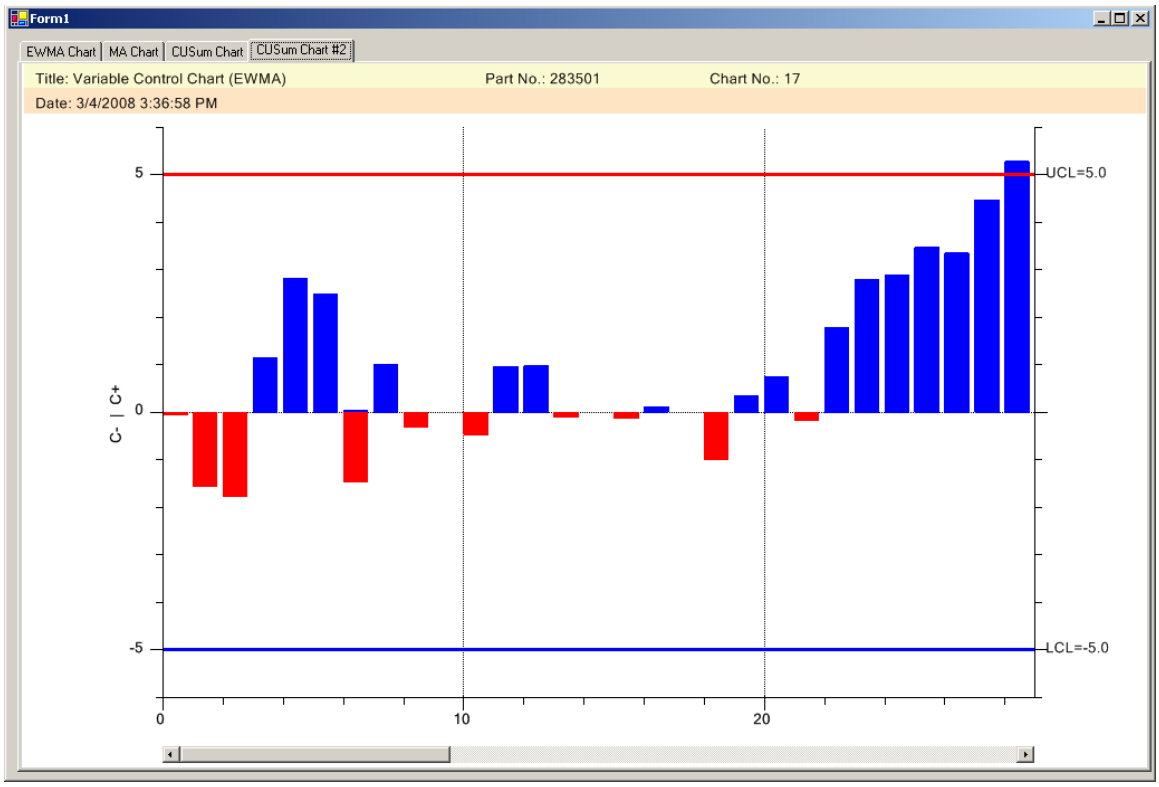
MAMS Chart – Moving Average / Moving Sigma

MAMS (Moving Average/Moving Sigma) Chart with Sample Values Plotted



The MAMS chart combines our Moving Average chart with a Moving Sigma chart. The Moving Average chart is primary (topmost) chart, and the Moving Sigma chart is the secondary (bottom) chart. It uses a single sample/subgroup, same as our standard [Individual-Range], [Moving Average], [EWMA], and [Moving Average] charts. When calculating the Moving Sigma, it windows the same data values used in the Moving Average calculation. Note that the limits are variable (wider) at the beginning, taking into account the fewer samples in the start up of any type of SPC chart which uses a sliding window in the calculation of moving average and moving sigma statistics.

Tabular CuSum Chart



CuSum Chart – Tabular, one-sided, upper and lower cumulative sum

The CuSum chart is a specialized control chart, which like the EWMA and MA charts, is considered to be more efficient that the Shewhart charts at detecting small shifts in the process mean, particularly if the mean shift is less than 2 sigma. There are several types of CuSum charts, but the easiest to use and the most accurate is considered the tabular CuSum chart and that is the one implemented in this software. The tabular cusum works by accumulating deviations that are above the process mean in one statistic (C+) and accumulating deviations below the process mean in a second statistic (C-). If either statistic (C+ or C-) falls outside of the calculated limits, the process is considered out of control.

Measured Data and Calculated Value Tables

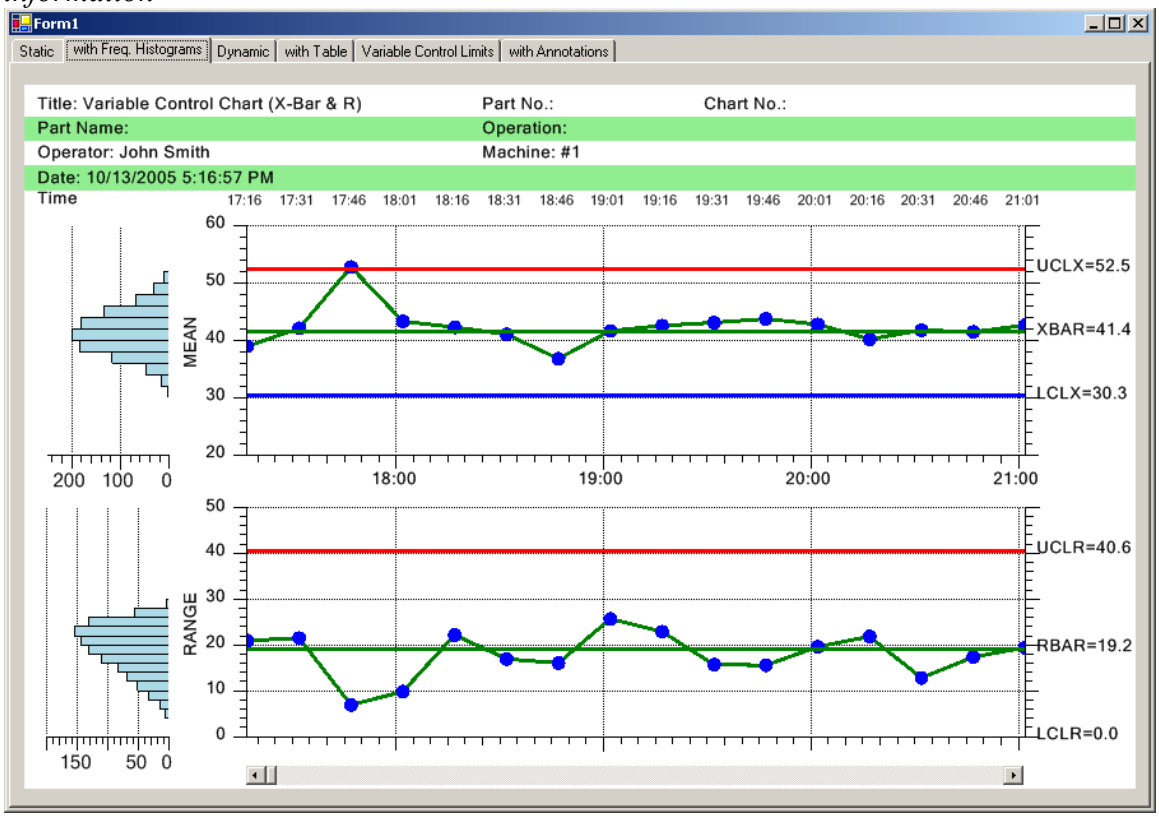
Standard worksheets used to gather and plot SPC data consist of three main parts.

5 The first part is the header section, identifying the title of the chart, the monitored process, the machine operator, part number and other important information specific to the chart.

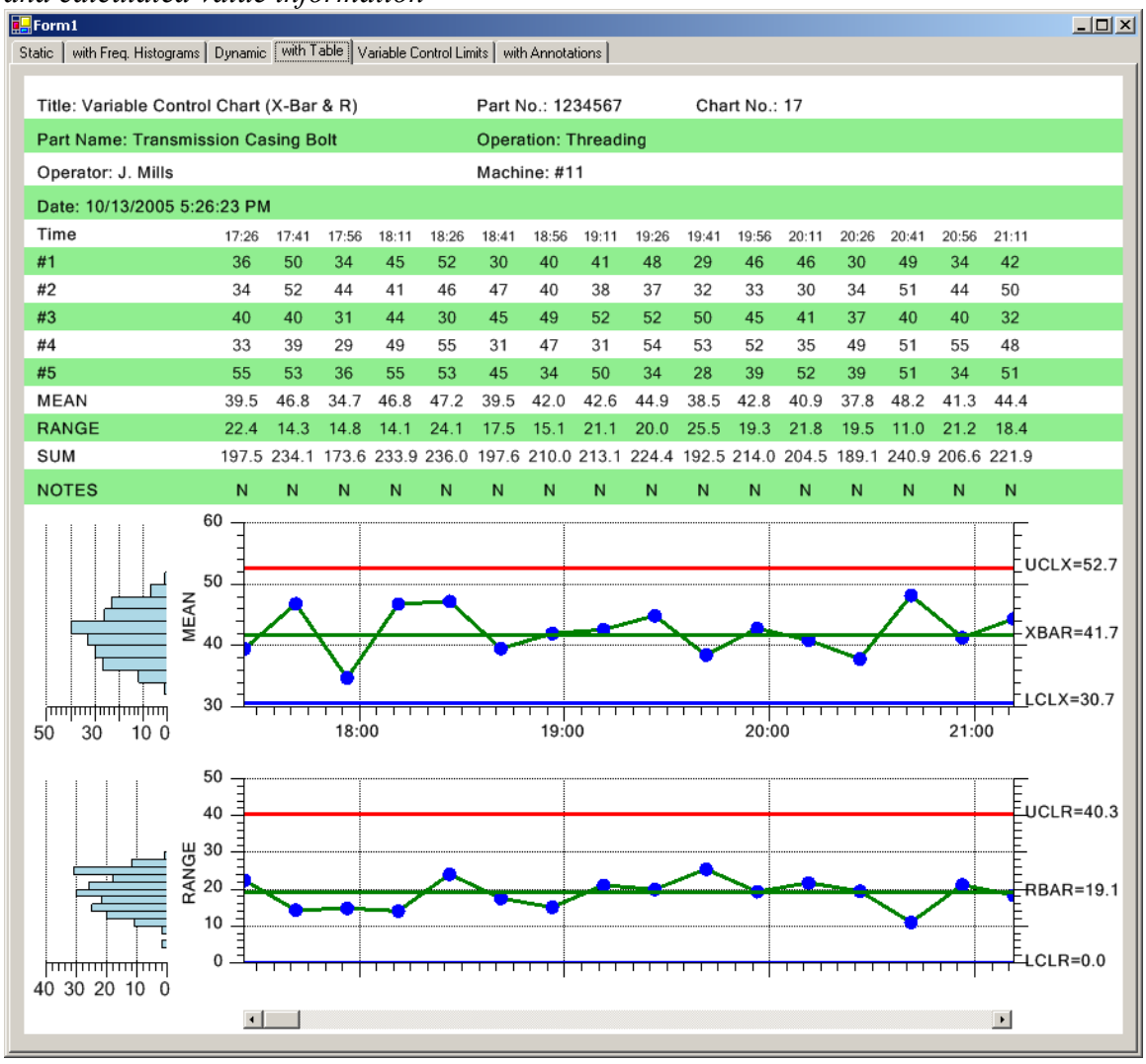
- The second part is the measurement data recording and calculation section, organized as a table, recording the sampled and calculated data in a neat, readable fashion.
- The third part, the actual SPC chart, plots the calculated SPC values for the sample group

The *Variable Control Chart* templates that we have created have options that enable the programmer to customize and automatically include header information along with a table of the measurement and calculated data, in the SPC chart. Enable the scrollbar option and you can display the tabular measurement data and SPC plots for a window of 8-20 subgroups, from a much larger collection of measurement data represented hundreds or even thousands of subgroups, and use the scrollbar to move through the data, similar to paging through a spreadsheet.

Scrollable Time-Based XBar-R Chart with frequency histograms and basic header information



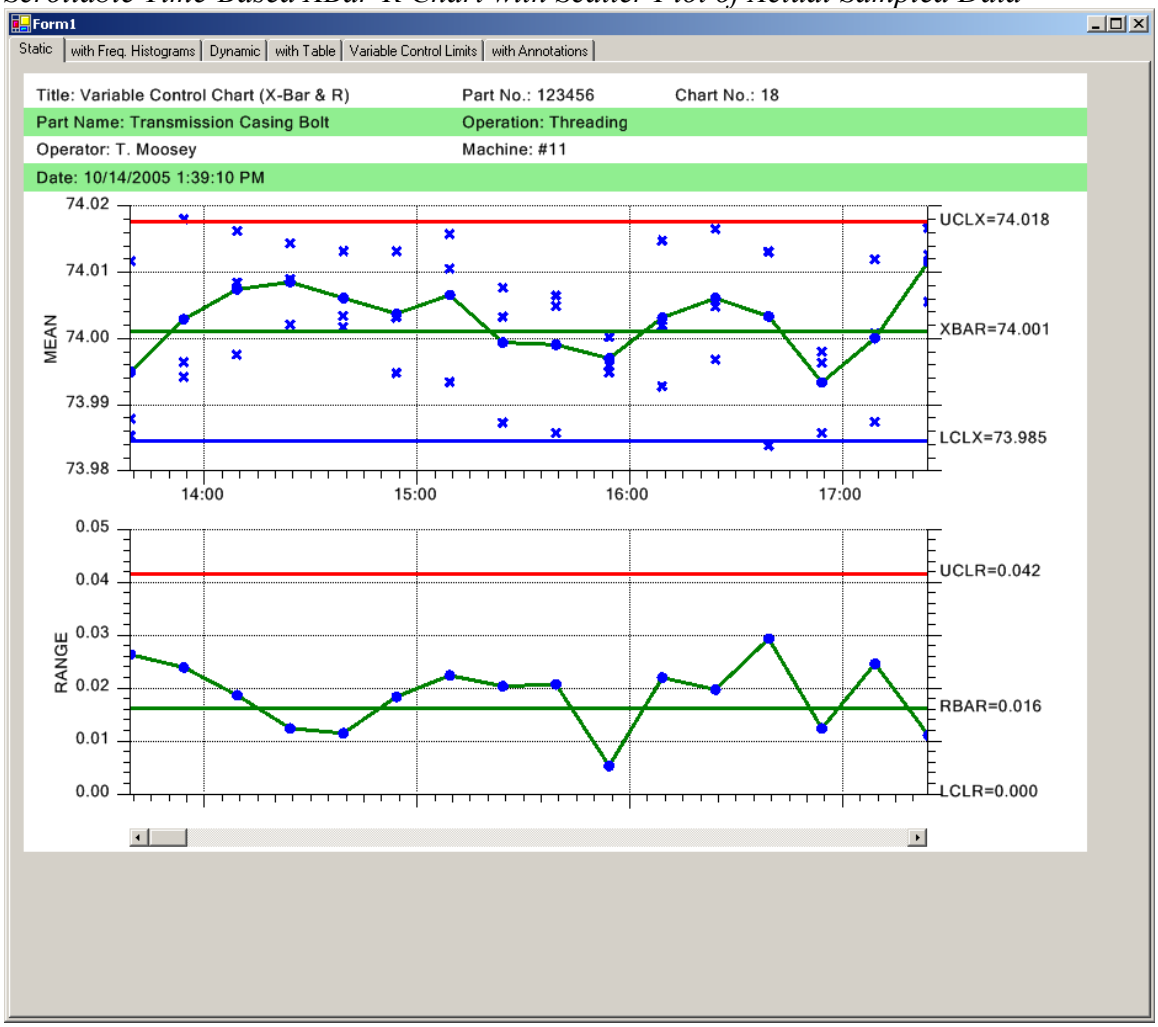
Scrollable Time-Based XBar-R Chart with frequency histograms, header, measurement and calculated value information



Scatter Plots of the Actual Sampled Data

In some cases it useful to plot the actual values of a sample subgroup along with the sample subgroup mean or median. Plot these samples in the SPC chart using additional scatter plots.

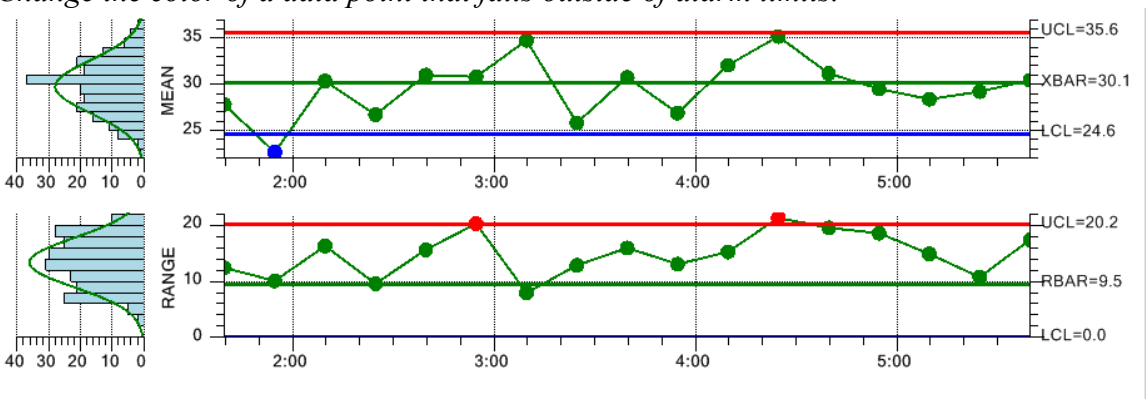
Scrollable Time-Based XBar-R Chart with Scatter Plot of Actual Sampled Data



Alarm Notification

Typically, when a process value exceeds a control limit, an alarm condition exists. In order to make sure that the program user identifies an alarm you can emphasize the alarm in several different ways. You can trap the alarm condition using an event delegate, log the alarm to the notes log, highlight the data point symbol in the chart where the alarm occurs, display an alarm status line in the data table, or highlight the entire column of the sample interval where the alarm occurs.

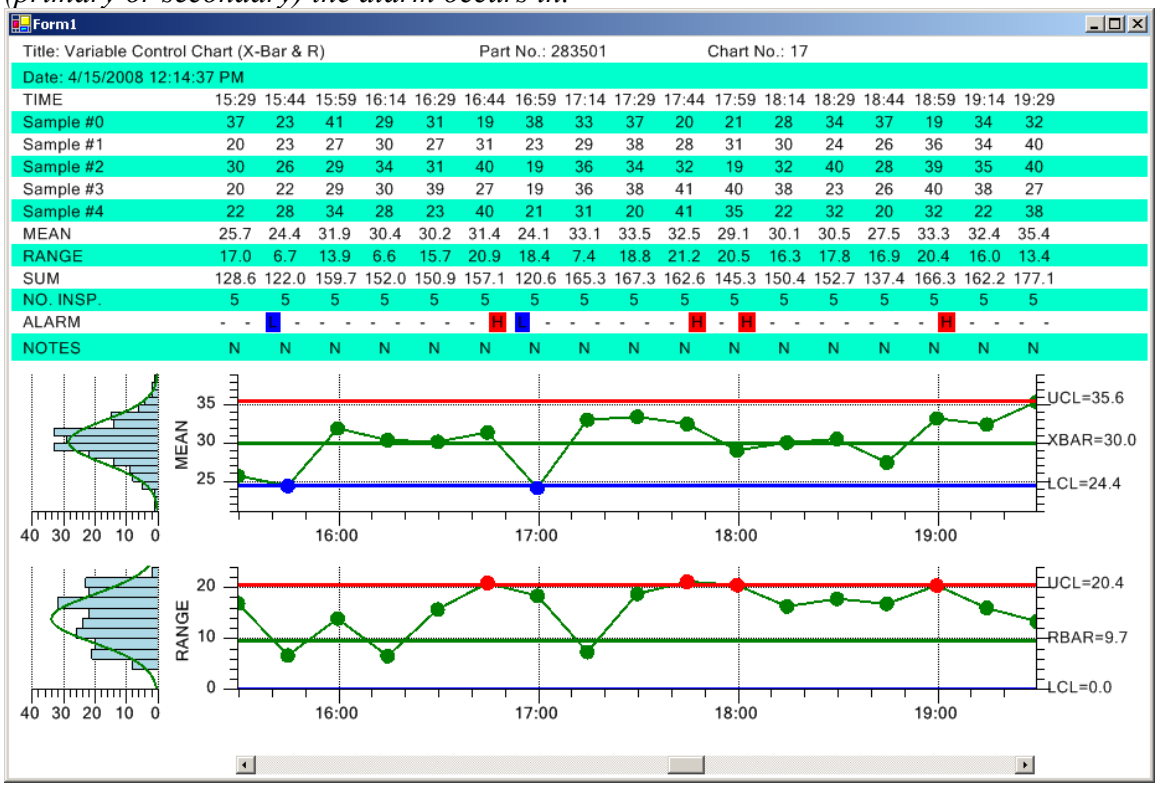
Change the color of a data point that falls outside of alarm limits.



Highlight the column of the sample interval where the alarm occurs

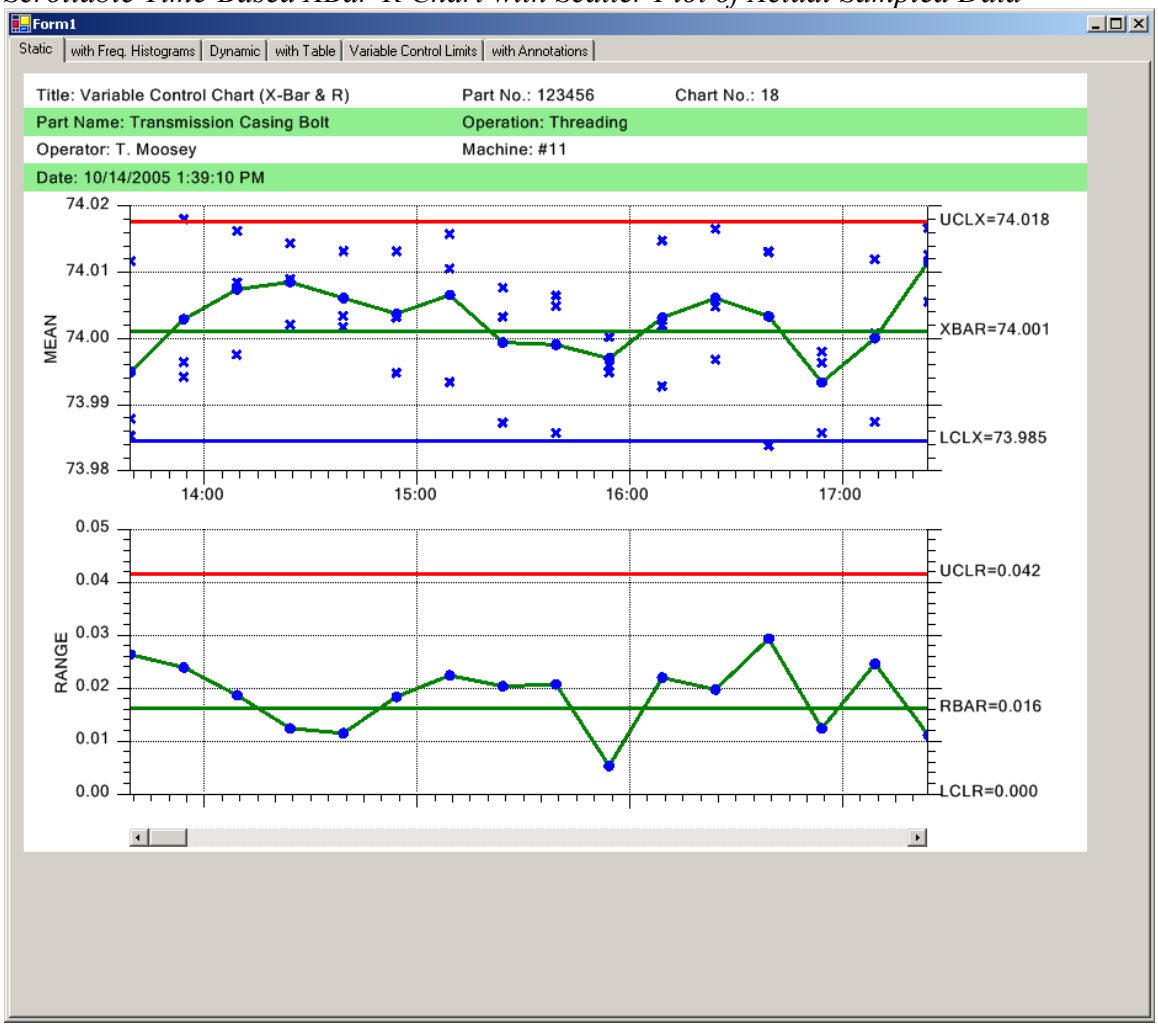
Title: Variable Control Chart (X-Bar & R)						Part No.: 283501					Chart No.: 17					
Date: 4/15/2008 12:09:38 PM																
TIME	1:39	1:54	2:09	2:24	2:39	2:54	3:09	3:24	3:39	3:54	4:09	4:24	4:39	4:54	5:09	5:24	5:39
Sample #0	33	26	23	31	37	29	38	30	31	25	32	40	34	34	30	32	23
Sample #1	21	19	24	32	34	33	30	19	24	25	37	41	41	30	28	26	32
Sample #2	33	19	40	25	21	20	36	23	26	20	22	19	28	23	19	30	29
Sample #3	27	20	36	22	33	32	36	25	32	32	34	38	21	21	31	34	41
Sample #4	25	29	28	24	30	40	34	32	40	33	35	38	32	39	34	23	27
MEAN	27.8	22.6	30.4	26.7	31.0	30.8	34.8	25.8	30.8	26.9	32.1	35.2	31.2	29.5	28.4	29.2	30.4
RANGE	12.4	10.1	16.3	9.6	15.6	20.3	8.0	12.9	16.0	13.1	15.2	21.3	19.6	18.6	14.9	10.8	17.4
SUM	139.1	113.1	151.8	133.5	155.0	154.1	173.8	129.1	153.8	134.4	160.3	175.9	155.9	147.5	141.9	146.0	152.2
NO. INSP.	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
ALARM	- -	L	- - - - - -	-	H	- - - - - - - - - -	-	H	- - - - - - - - -								
NOTES	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N

An alarm status line highlights an alarm condition, and lets you know when chart the (primary or secondary) the alarm occurs in.



These alarm highlight features apply to both variable control and attribute control charts.

Scrollable Time-Based XBar-R Chart with Scatter Plot of Actual Sampled Data



Attribute Control Charts

Attribute Control Charts are a set of control charts specifically designed for tracking defects (also called non-conformities). These types of defects are binary in nature (yes/no), where a part has one or more defects, or it doesn't. Examples of defects are paint scratches, discolorations, breaks in the weave of a textile, dents, cuts, etc. Think of the last car that you bought. The defects in each sample group are counted and run through some statistical calculations. Depending on the type of *Attribute Control Chart*, the number of defective parts are tracked (p-chart and np-chart), or alternatively, the number of defects are tracked (u-chart, c-chart). The difference in terminology "number of defective parts" and "number of defects" is highly significant, since a single part not only can have multiple defect categories (scratch, color, dent, etc), it can also have multiple defects per category. A single part may have 0 – N defects. So keeping track of

the number of defective parts is statistically different from keeping track of the number of defects. This affects the way the control limits for each chart are calculated.

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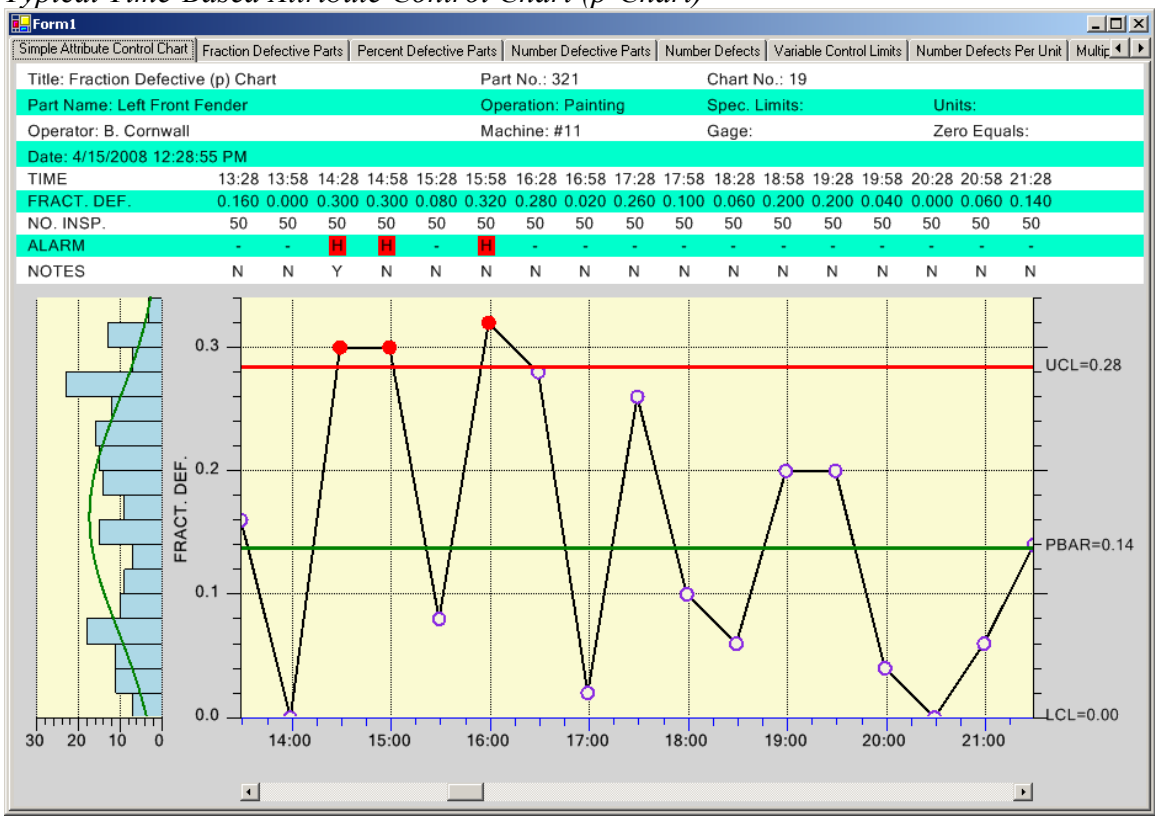
Attribute Control Charts are a set of control charts specifically designed for tracking defects (also called non-conformities). These types of defects are binary in nature (yes/no), where a part has one or more defects, or it doesn't. Examples of defects are paint scratches, discolorations, breaks in the weave of a textile, dents, cuts, etc. Think of the last car that you bought. The defects in each sample group are counted and run through some statistical calculations. Depending on the type of *Attribute Control Chart*, the number of defective parts are tracked (p-chart and np-chart), or alternatively, the number of defects are tracked (u-chart, c-chart). The difference in terminology "number of defective parts" and "number of defects" is highly significant, since a single part not only can have multiple defect categories (scratch, color, dent, etc), it can also have multiple defects per category. A single part may have 0 – N defects. So keeping track of the number of defective parts is statistically different from keeping track of the number of defects. This affects the way the control limits for each chart are calculated.

Typical Time-Based Attribute Control Chart (p-Chart)

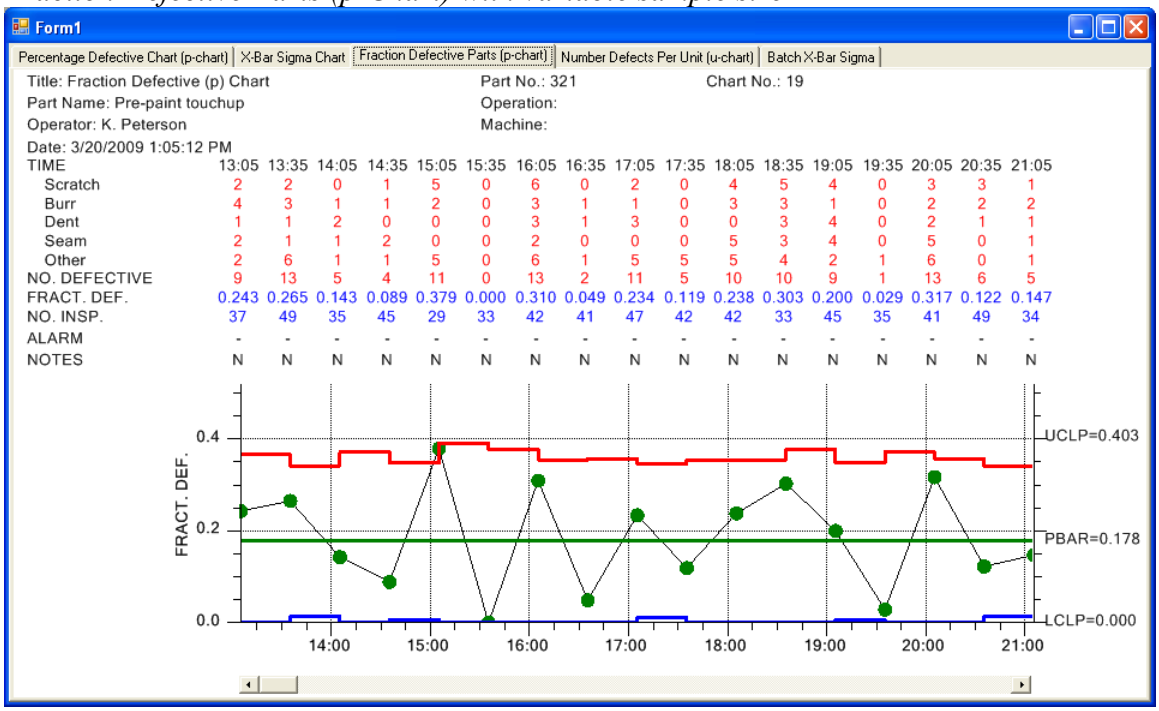

Form1
Simple Attribute Control Chart
Fraction Defective Parts
Percent Defective Parts
Number Defective Parts
Number Defects
Variable Control Limits
Number Defects Per Unit
Title: Fraction Defective (p) Chart
Part No.: 321
Chart No.: 19
Part Name: Left Front Fender
Operation: Painting
Spec. Limits:
Units:
Operator: B. Cornwall
Machine: #11
Gage:
Zero Equals:
Date: 4/15/2008 12:28:55 PM
TIME 13:28 13:58 14:28 14:58 15:28 15:58 16:28 16:58 17:28 17:58 18:28 18:58 19:28 19:58 20:28 20:58 21:28
FRACT. DEF. 0.160 0.000 0.300 0.300 0.080 0.320 0.280 0.020 0.260 0.100 0.060 0.200 0.200 0.040 0.000 0.060 0.140
NO. INSP. 50 50 50 50 50 50 50 50 50 50 50 50 50 50 50 50 50
ALARM - - H H - H - - - - - - - - - - -
NOTES N N Y N N N N N N N N N N N N N N
FRACT. DEF.
0.3
0.2
0.1
0.0
UCL=0.28
PBAR=0.14
LCL=0.00
30 20 10 0
14:00 15:00 16:00 17:00 18:00 19:00 20:00 21:00

p-Chart - Also known as the Percent or Fraction Defective Parts Chart

For a sample subgroup, the number of defective parts is measured and plotted as either a percentage of the total subgroup sample size, or a fraction of the total subgroup sample size. Since the plotted value is a fraction or percent of the sample subgroup size, the size of the sample group can vary without rendering the chart useless.

The p-Chart chart can also be used if the sample subgroup size varies from sampling interval to sampling interval. In this case, the control chart high and low limits vary from sample interval to sample interval, depending on the number of samples in the associated sample subgroup. A low number of samples in the sample subgroup make the band between the high and low limits wider than if a higher number of samples are available. Both the *Fraction Defective Parts and Percent Defective Parts* control charts come in versions that support variable sample sized for a subgroup.

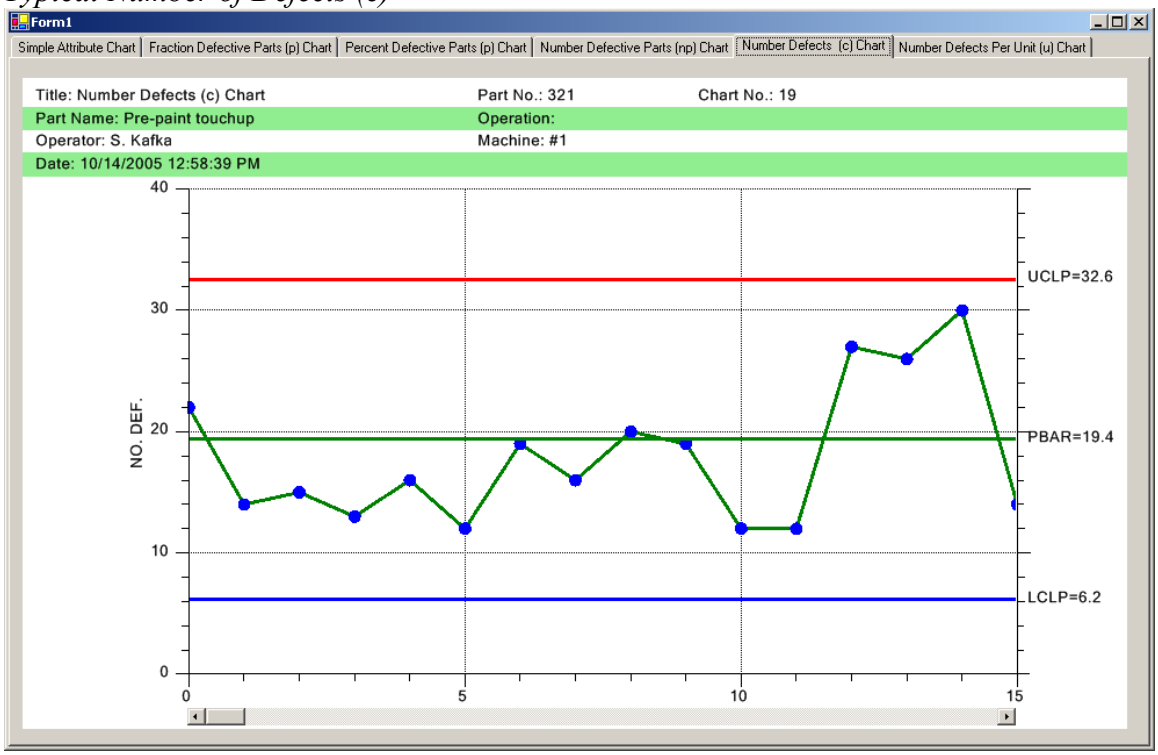
Fraction Defective Parts (p-Chart) with variable sample size



np-Chart – Also known as the Number Defective Parts Chart

For a sample subgroup, the number of defective parts is measured and plotted as a simple count. Statistically, in order to compare number of defective parts for one subgroup with the other subgroups, this type of chart requires that the subgroup sample size is fixed across all subgroups.

Typical Number of Defects (c)



c-Chart - Also known as the Number of Defects or Number of Non-Conformities Chart

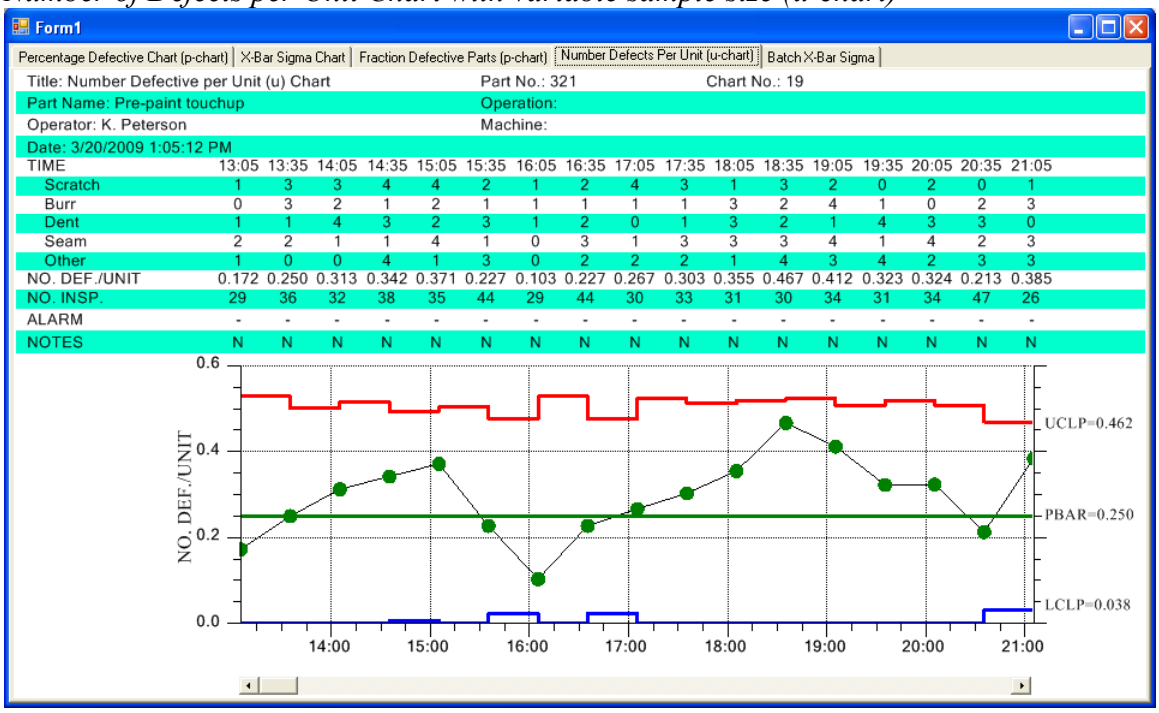
For a sample subgroup, the number of times a defect occurs is measured and plotted as a simple count. Statistically, in order to compare number of defects for one subgroup with the other subgroups, this type of chart requires that the subgroup sample size is fixed across all subgroups.

u-Chart – Also known as the Number of Defects per Unit or Number of Non-Conformities per Unit Chart

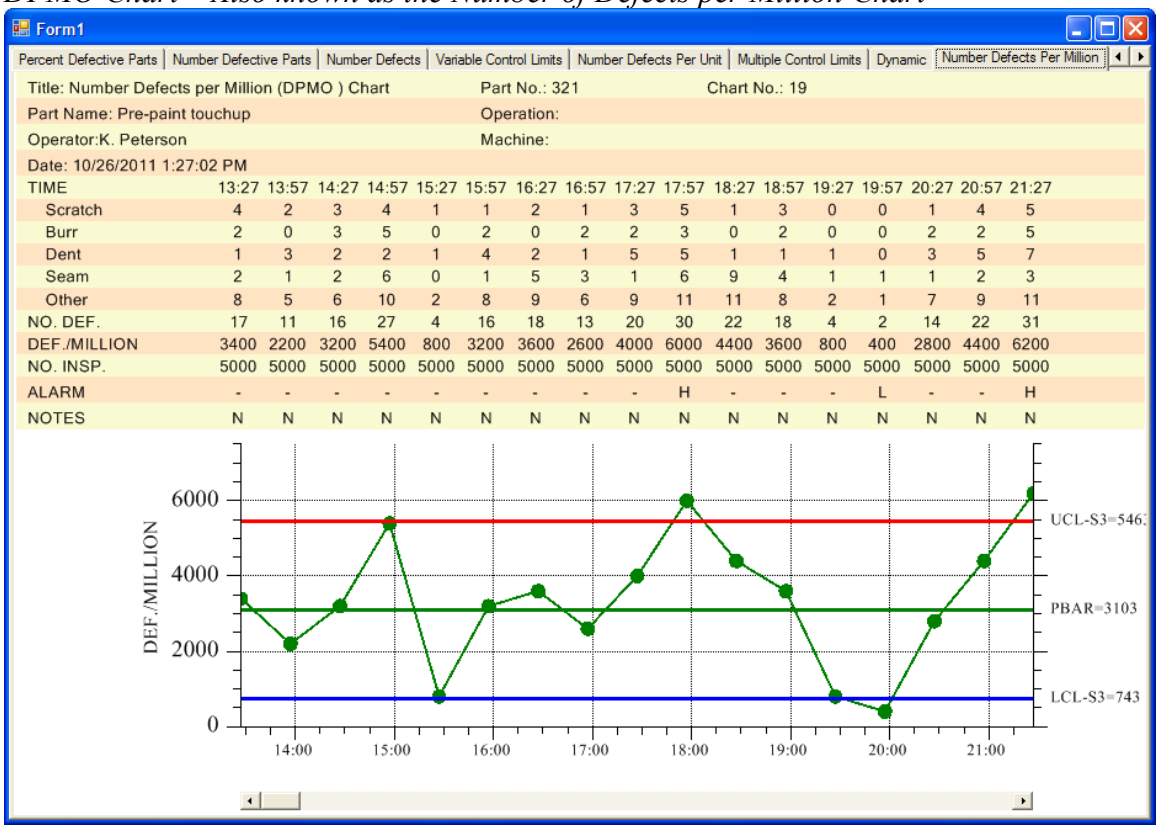
For a sample subgroup, the number of times a defect occurs is measured and plotted as either a percentage of the total subgroup sample size, or a fraction of the total subgroup sample size. Since the plotted value is a fraction or percent of the sample subgroup size, the size of the sample group can vary without rendering the chart useless.

The u-Chart chart can also be used if the sample subgroup size varies from sampling interval to sampling interval. In this case, the control chart high and low limits vary from sample interval to sample interval, depending on the number of samples in the associated sample subgroup. A low number of samples in the sample subgroup make the band between the high and low limits wider than if a higher number of samples are available.

Number of Defects per Unit Chart with variable sample size (u-chart)



DPMO Chart – Also known as the Number of Defects per Million Chart



This Attribute Control chart is a combination of the u-chart and the c-chart. The chart normalizes the defect rate, expressing it as defects per million. The chart displays the defect rate as defects per million. The table above gives the defect count in both absolute terms, and in the normalized defects per million used by the chart.

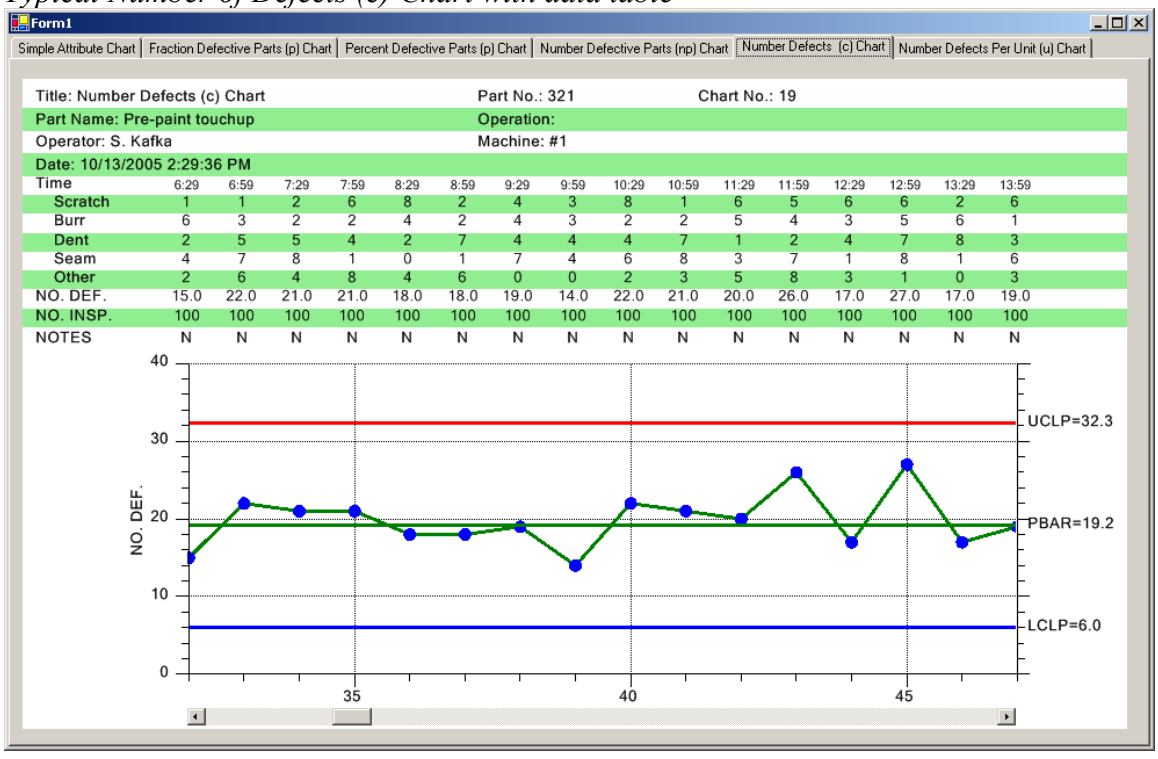
Defect and Defect Category Data Tables

As discussed under the *Variable Control Chart* section, standard worksheets used to gather and plot SPC data consist of three main parts.

- The first part is the header section, identifying the title of the chart, the monitored process, the machine operator, part number and other important information specific to the chart.
- The second part records the defect data, organized as a table recording the defect data and SPC calculations in a neat, readable fashion.
- The third part plots the calculated SPC values in the actual SPC chart.

The *Attribute Control Chart* templates that we have created have options that enable the programmer to customize and automatically include header information along with a table of the defect data, organized by defect category, number of defective parts, or total number of defects. Enable the scrollbar and you can display the tabular defect data and SPC plots for a window of 8-20 subgroups, from a much larger collection of measurement data representing hundreds or even thousands of subgroups, and use the scrollbar to move through the data, similar to paging through a spreadsheet.

Typical Number of Defects (c) Chart with data table

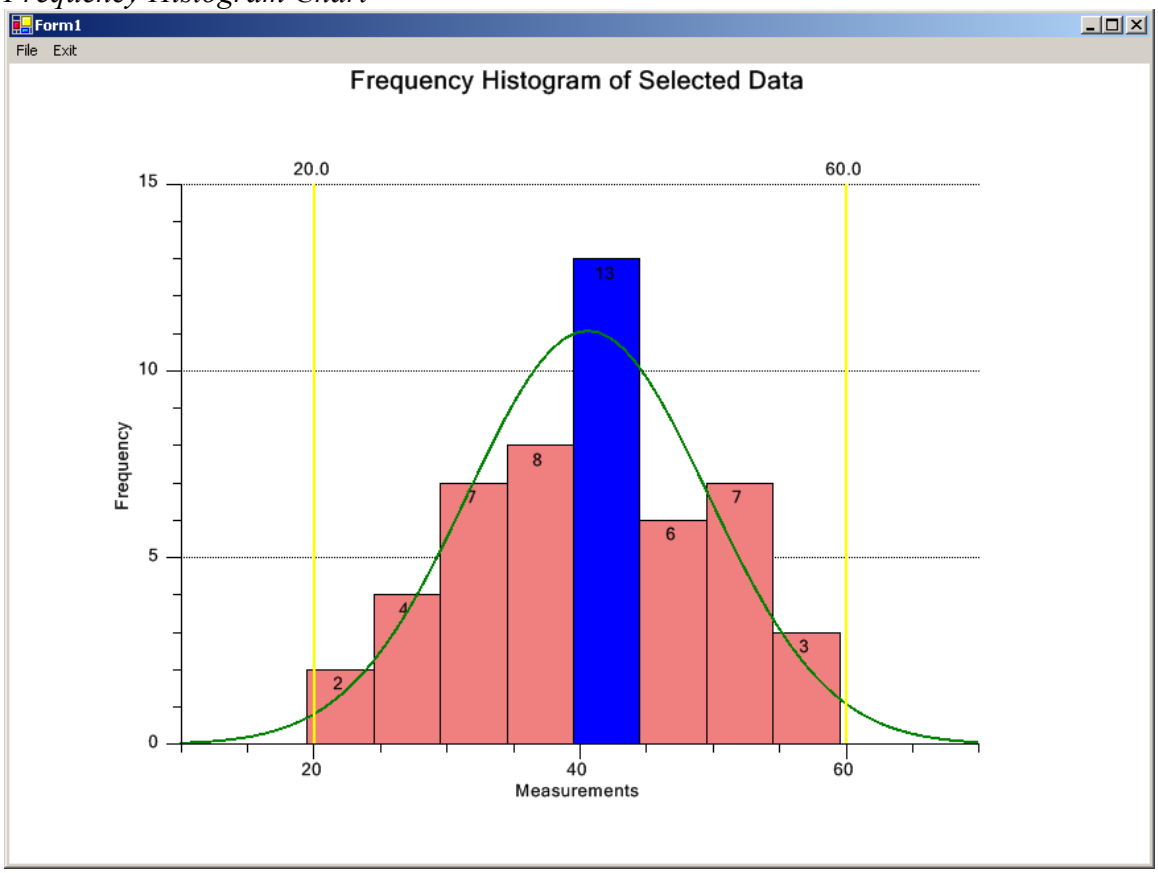

Form1
Simple Attribute Chart
Fraction Defective Parts (p) Chart
Percent Defective Parts (p) Chart
Number Defective Parts (np) Chart
Number Defects (c) Chart
Number Defects Per Unit (u) Chart
Title: Number Defects (c) Chart
Part No.: 321
Chart No.: 19
Part Name: Pre-paint touchup
Operation:
Operator: S. Kafka
Machine: #1
Date: 10/13/2005 2:29:36 PM
Time 6:29 6:59 7:29 7:59 8:29 8:59 9:29 9:59 10:29 10:59 11:29 11:59 12:29 12:59 13:29 13:59
Scratch 1 1 2 6 8 2 4 3 8 1 6 5 6 6 2 6
Burr 6 3 2 2 4 2 4 3 2 2 5 4 3 5 6 1
Dent 2 5 5 4 2 7 4 4 4 7 1 2 4 7 8 3
Seam 4 7 8 1 0 1 7 4 6 8 3 7 1 8 1 6
Other 2 6 4 8 4 6 0 0 2 3 5 8 3 1 0 3
NO. DEF. 15.0 22.0 21.0 21.0 18.0 18.0 19.0 14.0 22.0 21.0 20.0 26.0 17.0 27.0 17.0 19.0
NO. INSP. 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100
NOTES N N N N N N N N N N N N N N N N
40
30
20
10
0
NO. DEF.
35
40
45
UCLP=32.3
PBAR=19.2
LCLP=6.0

Other Important SPC Charts

Frequency Histogram Chart

An SPC control chart tacks the trend of critical variables in a production environment. It is important that the production engineer understand whether or not changes or variation in the critical variables are natural variations due to the tolerances inherent to the production machinery, or whether or not the variations are due to some systemic, assignable cause that needs to be addressed. If the changes in critical variables are the result of natural variations, a frequency histogram of the variations will usually follow one of the common continuous (normal, exponential, gamma, Weibull) or discrete (binomial, Poisson, hypergeometric) distributions. It is the job of the SPC engineer to know what distribution best models his process. Periodically plotting of the variation of critical variables will give SPC engineer important information about the current state of the process. A typical frequency histogram looks like:

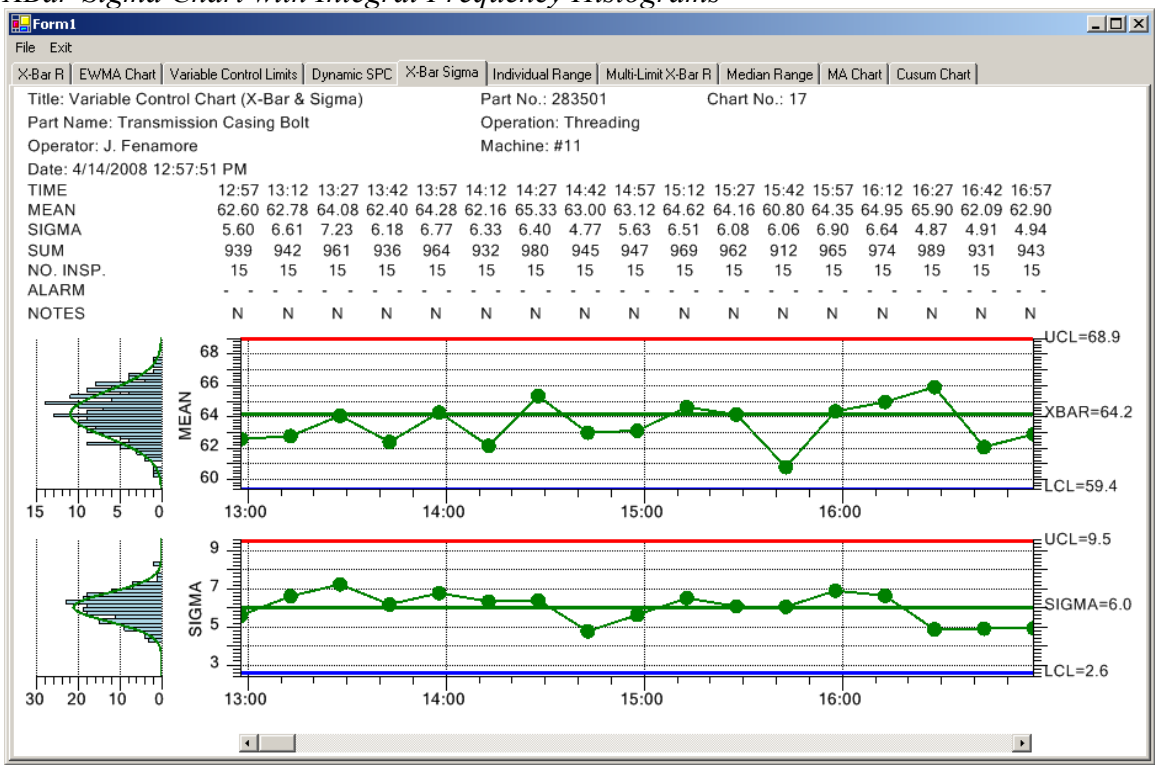
Frequency Histogram Chart



Viewing frequency histograms of both the variation in the primary variable (Mean, Median, count, or actual value), and the secondary variable (Range, Sigma or Moving

Range) side-by-side with the SPC control chart makes it even easier to find out whether the variations are the result of natural variations or the result of some systemic change in the process.

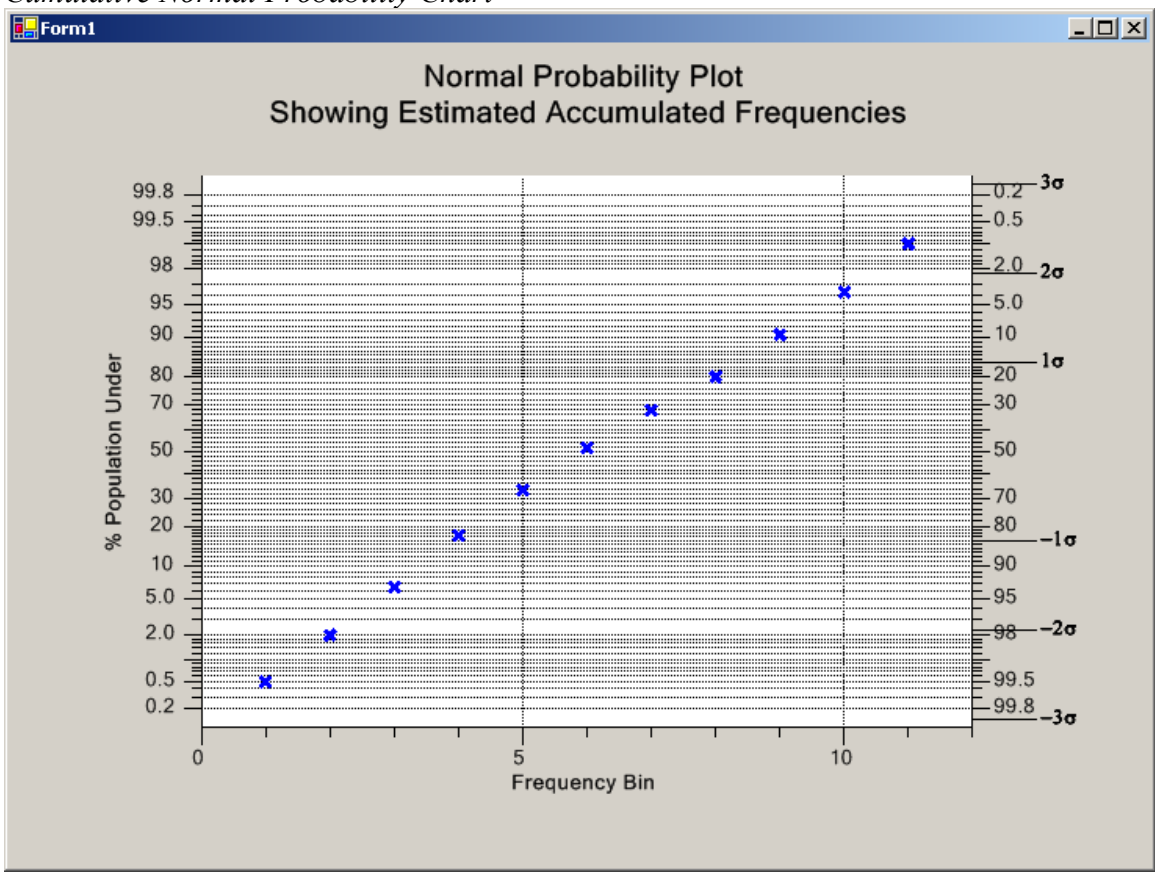
XBar-Sigma Chart with Integral Frequency Histograms



Probability Plots

Another important tool the SPC engineer uses to model the process variation is the probability plot. The probability plot tests whether control chart measurements fit a normal distribution. Usually, the SPC engineer plots probability plot graphs by hand using special probability plot graph paper. We added probability scale and axis classes to the **QCSPCChart** software that plots probability plots directly on the computer. Control chart measurements that follow a normal distribution curve plot as a straight line when plotted in a normal probability plot.

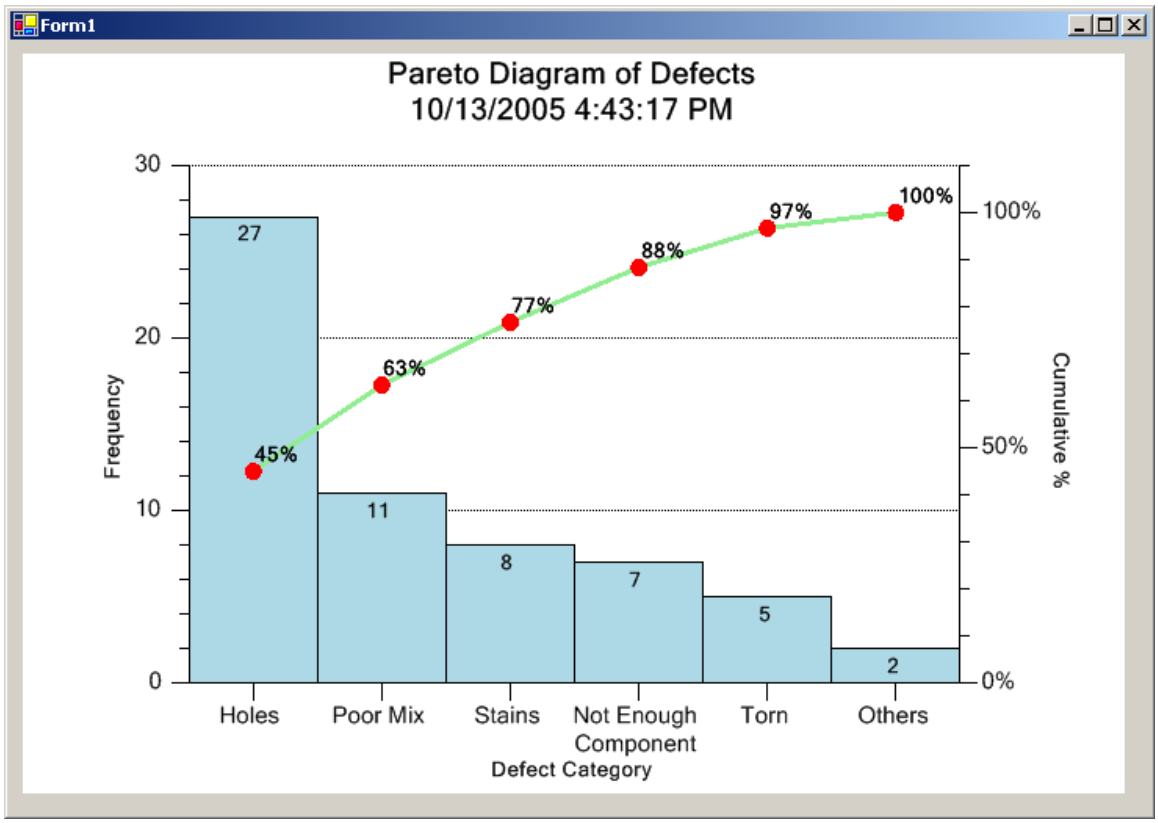
Cumulative Normal Probability Chart



Pareto Diagrams

The Pareto diagram is a special type of bar graph combined with a line plot, plotted in a chart that uses two different y-axis scales. The bar graph scale is a frequency scale that measures the number of times a specific problem has occurred. The line plot scale is a cumulative percentage scale.

Pareto Chart



The chart is easy to interpret. The tallest bar, the left-most one in a Pareto diagram, is the problem that has the most frequent occurrence. The shortest bar, the right-most one, is the problem that has the least frequent occurrence. Time spend on fixing the biggest problem will have the greatest affect on the overall problem rate. This is a simplistic view of actual Pareto analysis, which would usually take into account the cost effectiveness of fixing a specific problem. Never less, it is powerful communication tool that the SPC engineer can use in trying to identify and solve production problems.

3. Class Architecture of the SPC Control Chart Tools for .*Net* Class Library

Major Design Considerations

This chapter presents an overview of the **SPC Control Chart Tools for .*Net*** class architecture. It discusses the major design considerations of the architecture:

Major design consideration specific to **SPC Control Chart Tools for .*Net*** are:

- Direct support for the following SPC chart types:

Variable Control Charts

Fixed sample size subgroup control charts
- X-Bar R – (Mean and Range) chart
- X-Bar Sigma (Mean and Sigma) chart
- Median and Range (Median and Range) chart
- X-R (Individual Range Chart) chart
- EWMA (Exponentially Weighted Moving Average Chart)
- MA (Moving Average Chart)
- MAMR (Moving Average/Moving Range)
- MAMS (Moving Average/Moving Sigma)
- CuSum (Tabular Cumulative Sum Chart)

Variable sample size subgroup control charts
- X-Bar Sigma (Mean and Sigma Chart)

Attribute Control Charts

Fixed sample size subgroup control charts
- p-Chart (Fraction or Percent of Defective Parts, Fraction or Percent Non-Conforming)
- np Chart (Number of Defective Parts, Number of Non-Conforming)
- c-Chart (Number of Defects, Number of Non-Conformities)
- u-Chart (Number of Defects per Unit, Number of Non-Conformities Per Unit)
- DPMO (Number of Defects per Million)

Variable sample size subgroup control charts
- p Chart (Fraction or Percent of Defective Parts)
- u-Chart (Number of Defects per Unit)

SPC Analysis Charts

Frequency Histograms
Probability Charts
Pareto Charts

- Minimal programming required – create SPC charts with a few lines of code using our SPC chart templates.
- Integrated frequency histograms support – Display frequency histograms of sampled data, displayed side-by-side, sharing the same y-axis, with the SPC chart.
- Charts Header Information – Customize the chart display with job specific information, for example: Title, Operator, Part Number, Specification Limits, Machine, ect.
- Table display of SPC data – Display the sampled and calculated values for a SPC chart in a table, directly above the associated point in the SPC chart, similar to standardized SPC worksheets.
- Automatic calculation of SPC control limits – Automatically calculate SPC control limits using sampled data, using industry standard SPC control limit algorithms unique to each chart type.
- Automatic y-Axis scaling – Automatically calculated the y-axis scale for SPC charts, taking into account sampled and calculated data points, and any control limit lines added to the graph.
- Alarms – When monitored value exceeds a SPC control limit it can trigger an event that vectors to a user-written alarm processing delegate.
- SPC Process Capability Calculations -Variable Control Charts include Cp, Cpl, Cpu, Cpk, Cpm, Pp, Ppl, Ppu, and Ppk process capability statistics
- Notes – The operator can view or enter notes specific to a specific sample subgroup using a special notes tooltip.
- Data tooltips – The operator can view chart data values using a simple drill-down data tooltip display. The Data tooltips can optionally display sample subgroup data values and statistics, including process capability calculations (Cp, Cpl, Cpu, Cpk, Cpm, Pp, Ppl, Ppu, and Ppk) and customized using notes that have been entered for the sample subgroup.
- Data logging – SPC data (time stamp and/or batch number, sample values, calculated values, control limit values, and notes can be logged to disk in a CSV (commas separated value) file format.

- Scrollable view – Enable the scroll bar option and scroll through the chart and table view of the SPC data for an unlimited number of sample subgroups.

- Other, optional features – There are many optional features that SPC charts often use, including:

  Multiple SPC control limits, corresponding to +-1, 2 and 3 sigma limits.

  Scatter plots of all sampled data values on top of calculated means and medians.

  Data point annotations

The chapter also summarizes the classes in the **SPC Control Chart Tools for .*Net*** library.

SPC Control Chart Tools for .*Net* Class Summary

The **SPC Control Chart Tools for .*Net*** library is a super set of the **QCChart2D** library. The classes of the **QCChart2D** library are an integral part of the software. A summary of the **QCChart2D** classes appears below.

QCChart2D Class Summary

Chart view class — The chart view class is a UserControl subclass that manages the graph objects placed in the graph

Data classes — There are data classes for simple xy and group data types. There are also data classes that handle System.DateTime date/time data and contour data.

Scale transform classes — The scale transform classes handle the conversion of physical coordinate values to working coordinate values for a single dimension.

Coordinate transform classes — The coordinate transform classes handle the conversion of physical coordinate values to working coordinate values for a parametric (2D) coordinate system.

Attribute class — The attribute class encapsulates the most common attributes (line color, fill color, line style, line thickness, etc.) for a chart object.

Auto-Scale classes — The coordinate transform classes use the auto-scale classes to establish the minimum and maximum values used to scale a 2D coordinate system. The axis classes also use the

auto-scale classes to establish proper tick mark spacing values.

Charting object classes The chart object classes includes all objects placeable in a chart. That includes axes, axes labels, plot objects (line plots, bar graphs, scatter plots, etc.), grids, titles, backgrounds, images and arbitrary shapes.

Mouse interaction classes These classes, directly and indirectly System.EventHandler delegates that trap mouse events and permit the user to create and move data cursors, move plot objects, display tooltips and select data points in all types of graphs.

File and printer rendering These classes render the chart image to a printer, to a variety of file formats including JPEG, and BMP, or to a .Net Image object.

Miscellaneous utility classes Other classes use these for data storage, file I/O, and data processing.

For each of these categories see the associated description in the **QCChart2D** manual (QCChart2DNetManual.pdf). The **SPC Control Chart Tools for .*Net*** classes are in addition to the ones above. They are summarized below.

SPC Control Chart Tools for .Net Class Hierarchy

The **QCSPCChart** classes are a super set of the **QCChart2D** charting software. No attempt should be made to utilize the **QCSPCChart** classes without a good understanding of the **QCChart2D** classes. See the **QCChart2DNetManual** PDF file for detailed information about the **QCChart2D** classes. The diagram below depicts the class hierarchy of the **SPC Control Chart Tools for .*Net*** library without the additional **QCChart2D** classes

Namespace com.quinncurtis.spcchartnet.

com.quinn-curtis.chart2dnet.ChartView
- FrequencyHistogramChart
- ParetoChart
- ProbabilityChart
- SPCChartBase
  - SPCBatchAttributeControlChart
  - SPCBatchVariableControlChart
  - SPCTimeAttributeControlChart
  - SPCTimeVariableControlChart

com.quinncurtis.chart2dnet.AutoScale
    ProbabilityAutoScale
com.quinncurtis.chart2dnet.Axis
    ProbabilityAxis
com.quinncurtis.chart2dnet.LinearAxis
    ProbabilitySigmaAxis
com.quinncurtis.chart2dnet.PhysicalCoordinates
    ProbabilityCoordinates
com.quinncurtis.chart2dnet.Scale
    ProbabilityScale
com.quinncurtis.chart2dnet.StringLabel
    NotesLabel
com.quinncurtis.chart2dnet.MouseListener
    NotesToolTip
com.quinncurtis.chart2dnet.DataToolTip
    SPCDataToolTip

QCSPCChart Classes

SPCControlChartData
SPCControlLimitAlarmArgs
SPCControlLimitRecord
SPCCalculatedValueRecrod
SPCProcessCapabilityRecord
SPCSampledValueRecord
SPCControlParameters
SPCGeneralizedTableDisplay
SPCControlPlotObjects
SPCChartObjects

SPC Control Chart Data

SPCControlChartData

SPC control chart data is stored in the **SPCControlChartData** class. It holds the header information used to customize the chart table, the raw sample data used to prepare the chart, the calculated chart values used in the chart, and the SPC control limits. It contains array lists of **SPCSampledValueRecord**,

SPCControlLimitRecord and **SPCCalculatedValueRecord** objects.

SPCSampledValueRecord

This class encapsulates a sample data value. It includes a description for the item, the current value of the sampled value, and a history of previous values.

SPCControlLimitRecord

This class holds information specific to a SPC control limit: including the current value of the control limit, a history of control limit values, description, and the hysteresis value for alarm checking.

SPCCalculatedValueRecord

The record class for a calculated SPC statistic. It holds the calculated value type (mean, median, sum, variance, standard deviation, etc.), value, description and historical data.

SPCProcessCapabilityRecord

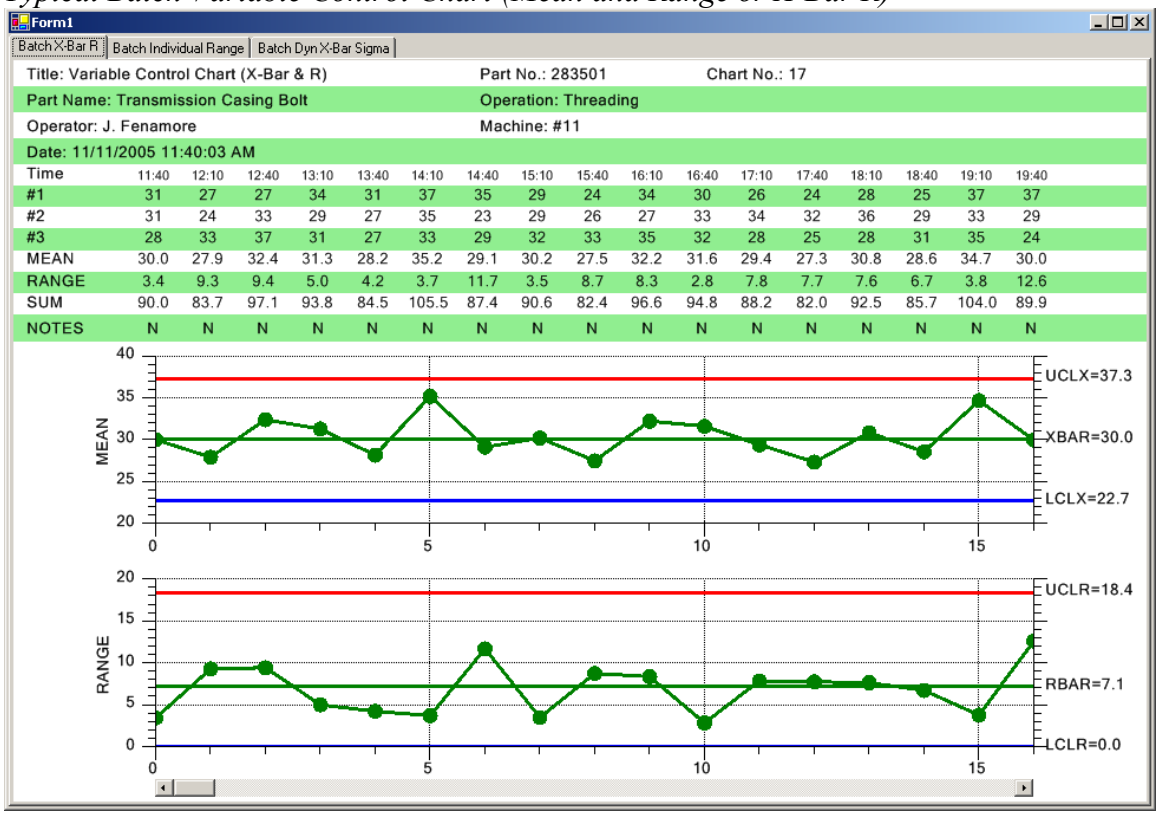
The record class for storing and calculating process capability statistics: Cp, Cpl, Cpu, Cpk, Cpm, Pp, Ppl, Ppu and Ppk.

SPC Charts and Related Chart Objects

SPCChartBase

The **SPCChartBase** forms the base object for all SPC control charts. The variable control chart templates (**SPCBatchVariableControlChart, and SPCTimeVariableControlChart**), and attribute control charts (**SPCBatchAttributeControlChart** and **SPCTimeAttributeControlChart**) are derived from the **SPCChartBase** class.

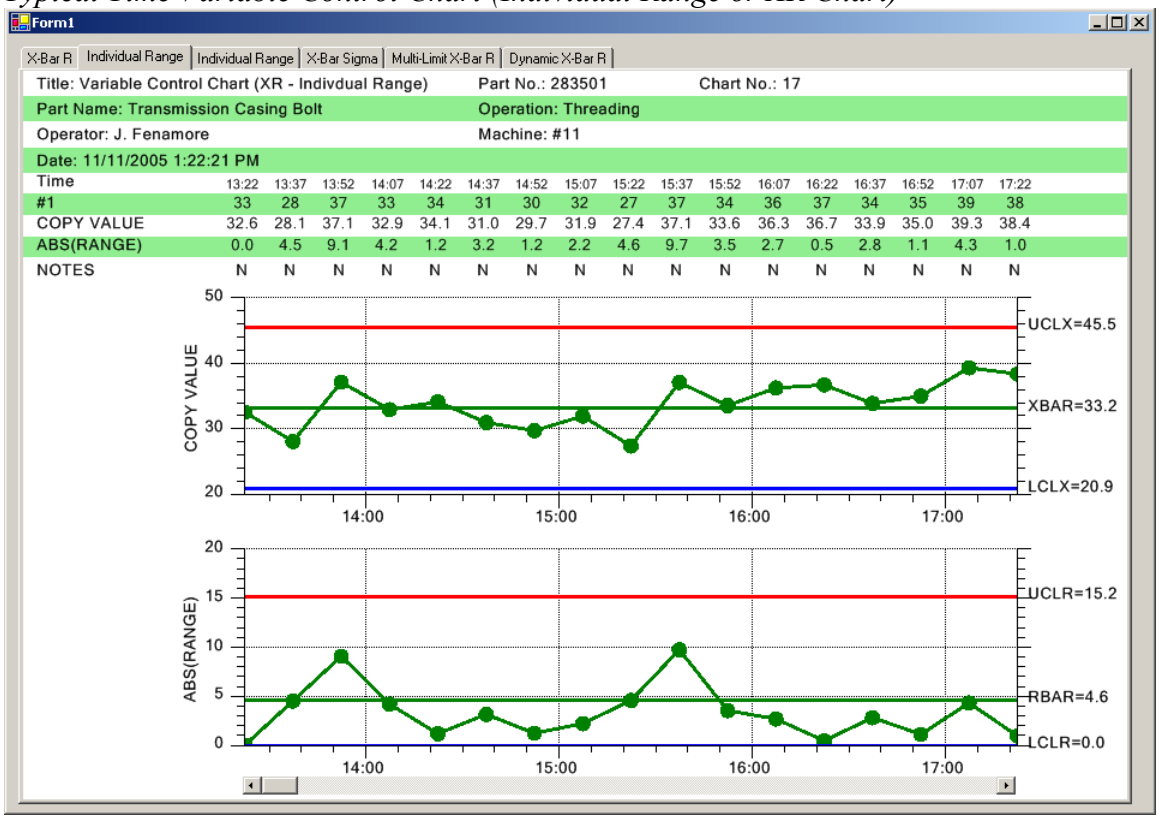
Typical Batch Variable Control Chart (Mean and Range or X-Bar R)



SPCBatchVariableControlChart

A *Batch Variable Control Chart* class that uses a **CartesianCoordinate** system with a numeric based X-Axis. This class creates MEAN_RANGE_CHART, MEDIAN_RANGE_CHART, INDIVIDUAL_RANGE_CHART, MEAN_SIGMA_CHART, MEAN_SIGMA_CHART_VSS, EWMA_CHART, TABCUSUM, MA_CHART, MAMR_CHART and MAMS_CHART chart types.

Typical Time Variable Control Chart (Individual Range or XR Chart)

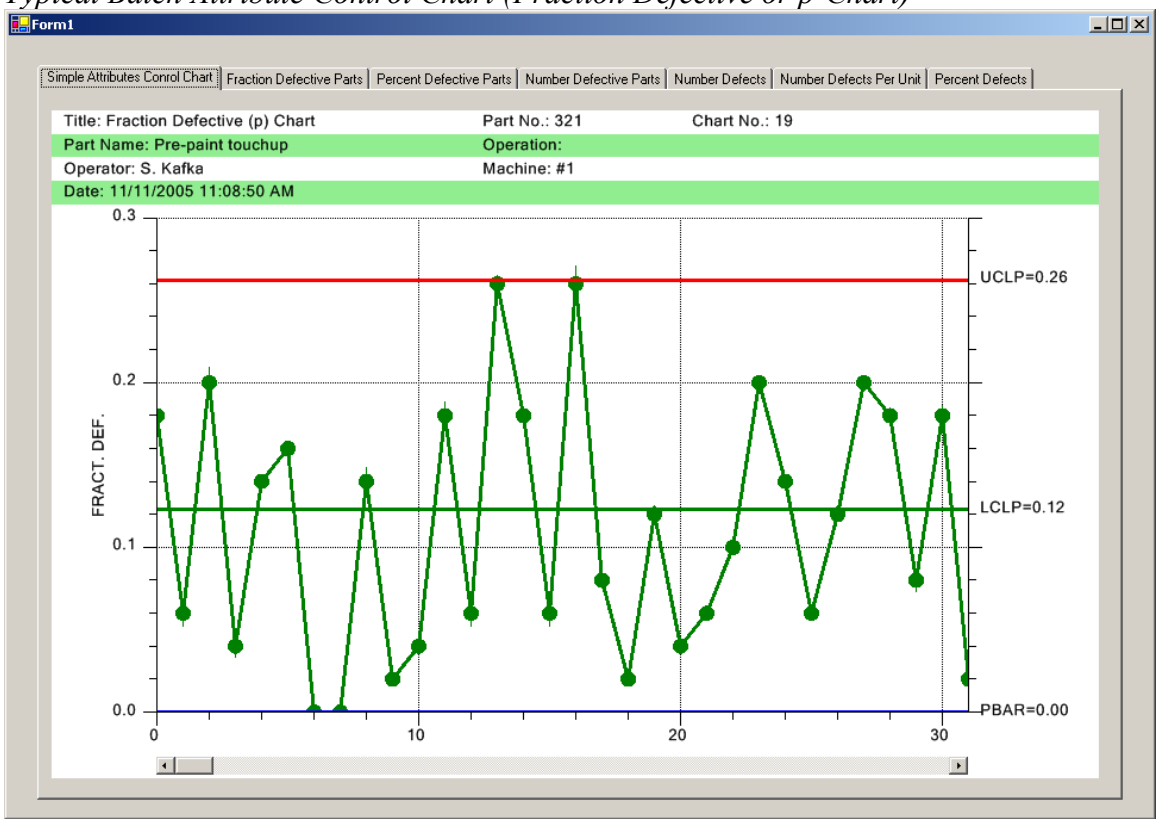


SPCTimeVariableControlChart

A *Variable Control Chart* class that uses a **TimeCoordinate** system with a time based X-Axis. This class creates MEAN_RANGE_CHART, MEDIAN_RANGE_CHART, INDIVIDUAL_RANGE_CHART, MEAN_SIGMA_CHART, MEAN_SIGMA_CHART_VSS, EWMA_CHART, TABCUSUM, MA_CHART, MAMR_CHART and MAMS_CHART chart types.

Typical SPCBatchCusumControlChart with alarm limits

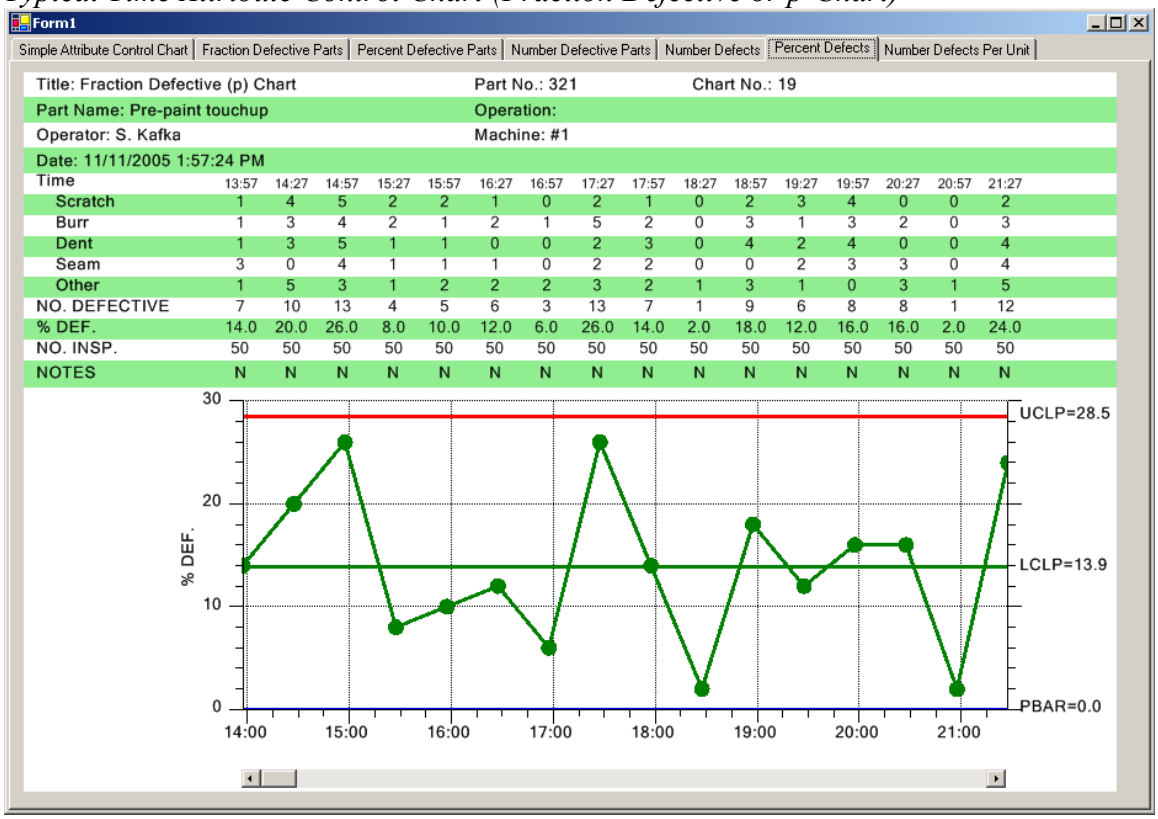
Typical Batch Attribute Control Chart (Fraction Defective or p-Chart)



SPCBatchAttributeControlChart

A Batch Attribute Control Chart class that uses a **CartesianCoordinate** system with a numeric X-Axis. This class creates PERCENT_DEFECTIVE_PARTS_CHART, FRACTION_DEFECTIVE_PARTS_CHART, NUMBER_DEFECTIVE_PARTS_CHART, NUMBER_DEFECTS_PERUNIT_CHART, NUMBER_DEFECTS_CHART SPC, NUMBER_DEFECTS_PER_MILLION_CHART, PERCENT_DEFECTIVE_PARTS_CHART_VSS, FRACTION_DEFECTIVE_PARTS_CHART_VSS, NUMBER_DEFECTS_PERUNIT_CHART_VSS chart types.

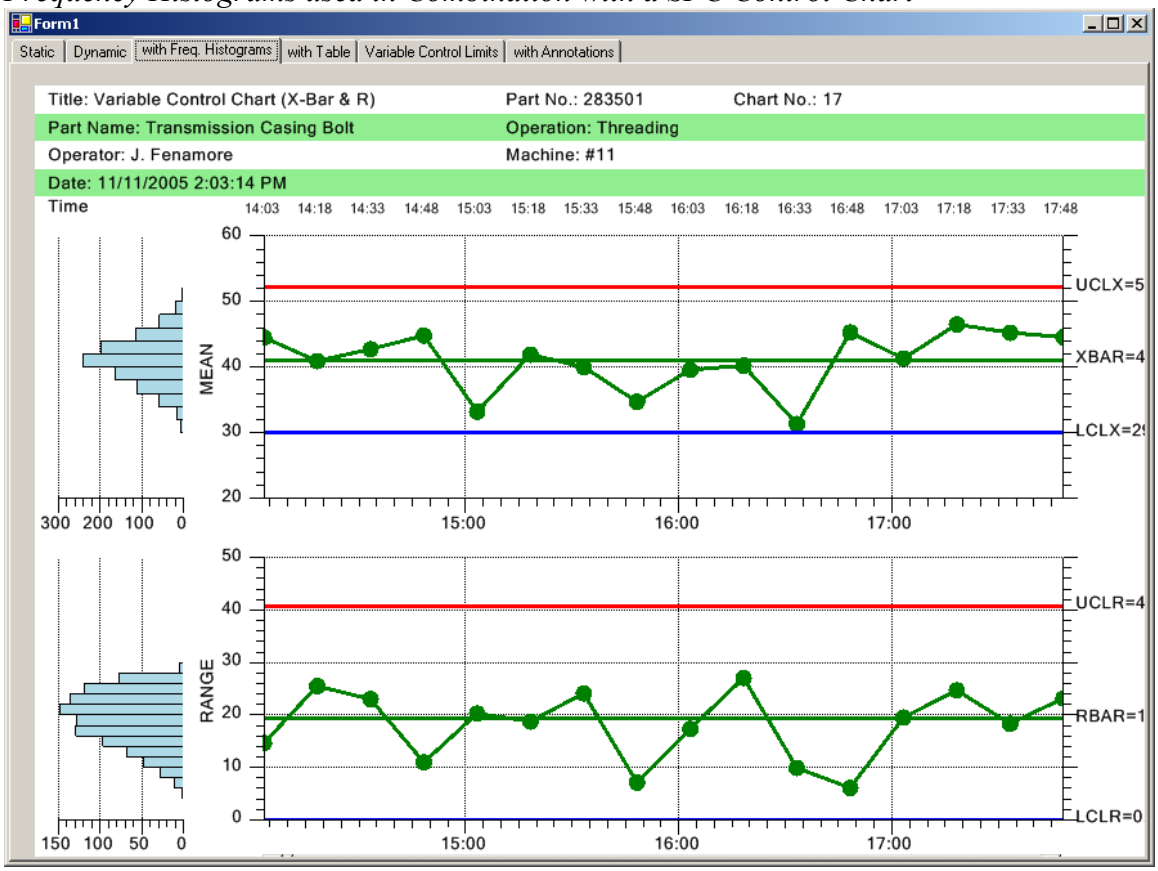
Typical Time Attribute Control Chart (Fraction Defective or p-Chart)


Form1
Simple Attribute Control Chart
Fraction Defective Parts
Percent Defective Parts
Number Defective Parts
Number Defects
Percent Defects
Number Defects Per Unit
Title: Fraction Defective (p) Chart
Part No.: 321
Chart No.: 19
Part Name: Pre-paint touchup
Operation:
Operator: S. Kafka
Machine: #1
Date: 11/11/2005 1:57:24 PM
Time 13:57 14:27 14:57 15:27 15:57 16:27 16:57 17:27 17:57 18:27 18:57 19:27 19:57 20:27 20:57 21:27
Scratch 1 4 5 2 2 1 0 2 1 0 2 3 4 0 0 2
Burr 1 3 4 2 1 2 1 5 2 0 3 1 3 2 0 3
Dent 1 3 5 1 1 0 0 2 3 0 4 2 4 0 0 4
Seam 3 0 4 1 1 1 0 2 2 0 0 2 3 3 0 4
Other 1 5 3 1 2 2 2 3 2 1 3 1 0 3 1 5
NO. DEFECTIVE 7 10 13 4 5 6 3 13 7 1 9 6 8 8 1 12
% DEF. 14.0 20.0 26.0 8.0 10.0 12.0 6.0 26.0 14.0 2.0 18.0 12.0 16.0 16.0 2.0 24.0
NO. INSP. 50 50 50 50 50 50 50 50 50 50 50 50 50 50 50 50
NOTES N N N N N N N N N N N N N N N N
30
20
10
0
% DEF.
UCLP=28.5
LCLP=13.9
PBAR=0.0
14:00
15:00
16:00
17:00
18:00
19:00
20:00
21:00

SPCTimeAttributeControlChart

An *Attribute Control Chart*class that uses a **TimeCoordinate** system with a time based X-Axis This class creates PERCENT_DEFECTIVE_PARTS_CHART, FRACTION_DEFECTIVE_PARTS_CHART, NUMBER_DEFECTIVE_PARTS_CHART, NUMBER_DEFECTS_PERUNIT_CHART, NUMBER_DEFECTS_CHART, NUMBER_DEFECTS_PER_MILLION_CHART, PERCENT_DEFECTIVE_PARTS_CHART_VSS, FRACTION_DEFECTIVE_PARTS_CHART_VSS, NUMBER_DEFECTS_PERUNIT_CHART_VSS chart types.

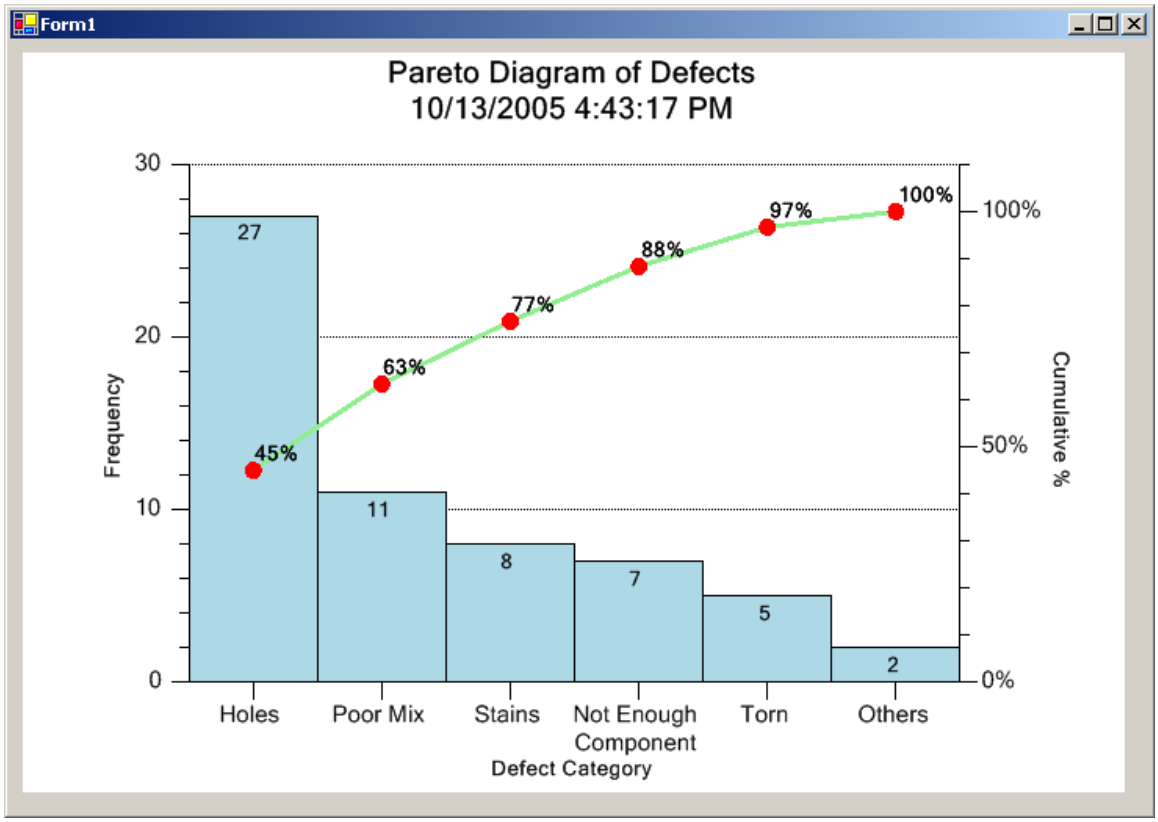
Frequency Histograms used in Combination with a SPC Control Chart



FrequencyHistogramChart

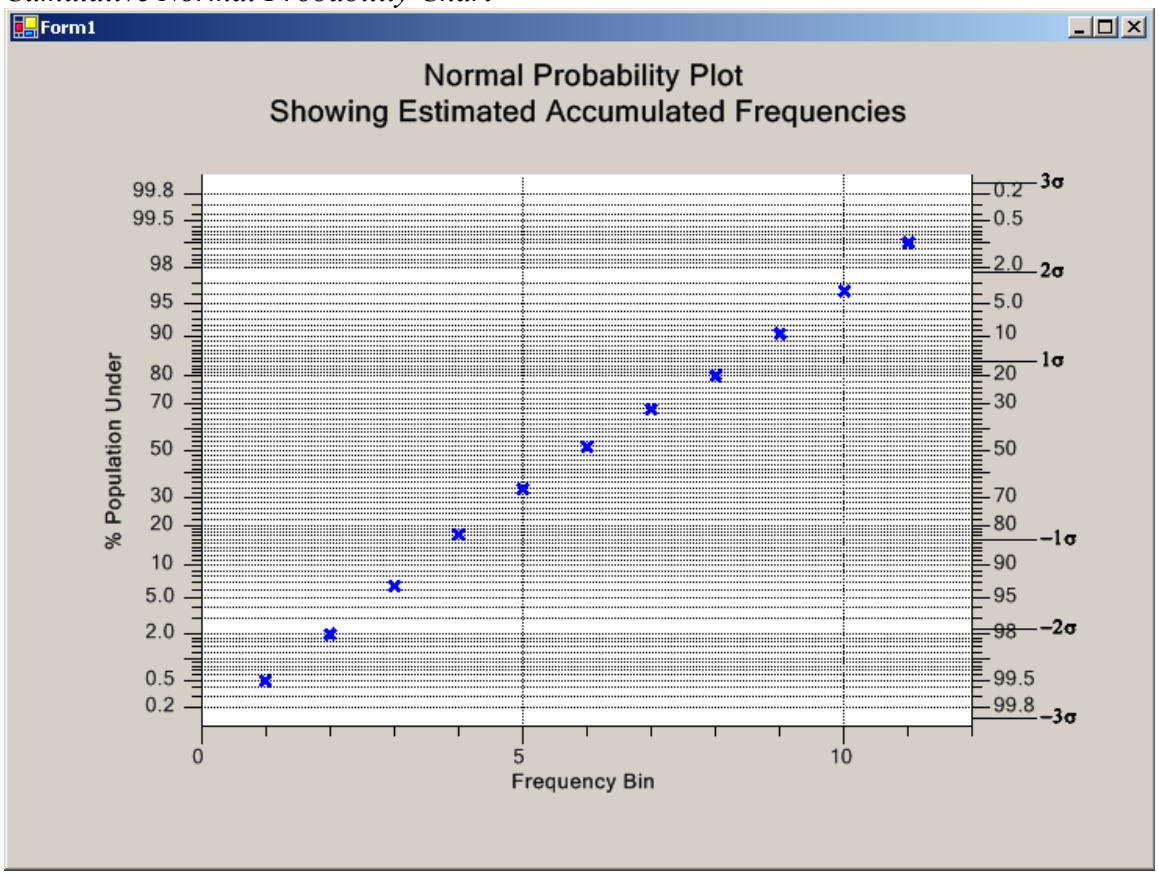
A *Frequency Histogram* checks that the variation in a process variable follows the predicted distribution function (normal, Poisson, chi-squared, etc). The class includes all of the objects needed to draw a complete frequency histogram chart. These objects include objects for data, a coordinate system, titles, axes, axes labels, grids and a bar plot.

Pareto Chart



ParetoChart The *Pareto Diagram* is special type of bar graph combined with a line plot, plotted in a chart that uses two different y-axis scales. The bar graph scale is a frequency scale that measures the number of times a specific problem has occurred. The line plot scale is a cumulative percentage scale. The class includes all of the objects needed to draw a complete Pareto chart. These objects include objects for data, coordinate systems, titles, axes, axes labels, grids, numeric labels, and a line plot and bar plot.

Cumulative Normal Probability Chart



Probability Plots

The **ProbabilityChart** class is a highly specialized chart template used to plot cumulative frequency data using a coordinate system that has a cumulative probability y-scale. The class includes all of the objects needed to draw a complete Probability chart. These objects include objects for data, coordinate systems, titles, axes, axes labels, grids, numeric labels, and scatter plot. New classes were developed for the **QCChart2D** charting software capable of rendering of probability chart coordinate systems (**ProbabilityScale**, **ProbabilityAutoScale**, **ProbabilityCoordinates**) and probability axes (**ProbabilityAxis**, **ProbabilitySigmaAxis**).

ProbabilityScale

The **ProbabilityScale** class implements a cumulative normal probability coordinate system for a single coordinate, x or y. Two such scales provide the scaling routines for x and y in an **PhysicalCoordindates** derived class, **CartesianCoordinates**, for example. This allows for different x and y scale types (linear, cumulative normal probability, time) to be installed independently for x- and y-coordinates.

ProbabilityAutoScale

The **ProbabilityAutoScale** class is used with cumulative normal probability coordinates and auto-scales the plotting area of graphs and to set the minimum and maximum values of the axes displayed in the graphs.

ProbabilityCoordinates

The **ProbabilityCoordinates** class extends the **PhysicalCoordinates** class to support a y-axis probability scale in an xy coordinate plane.

ProbabilityAxis The **ProbabilityAxis** class implements a probability axis where the major tick marks are placed at intervals appropriate to a cumulative probability scale.

ProbabilitySigmaAxis

The **ProbabilitySigmaAxis** class implements a linear axis where the tick marks are placed at linear intervals on the sigma levels of the associated probability scale.

NotesLabel The **NotesLabel** class displays the Notes items in the SPC table.

NotesToolTip The **NotesToolTip** displays the Notes tooltip for the notes items in the SPC table.

SPCDataToolTip The **SPCDataTooTip** displays the data tooltip for SPC Charts..

SPC Calculations

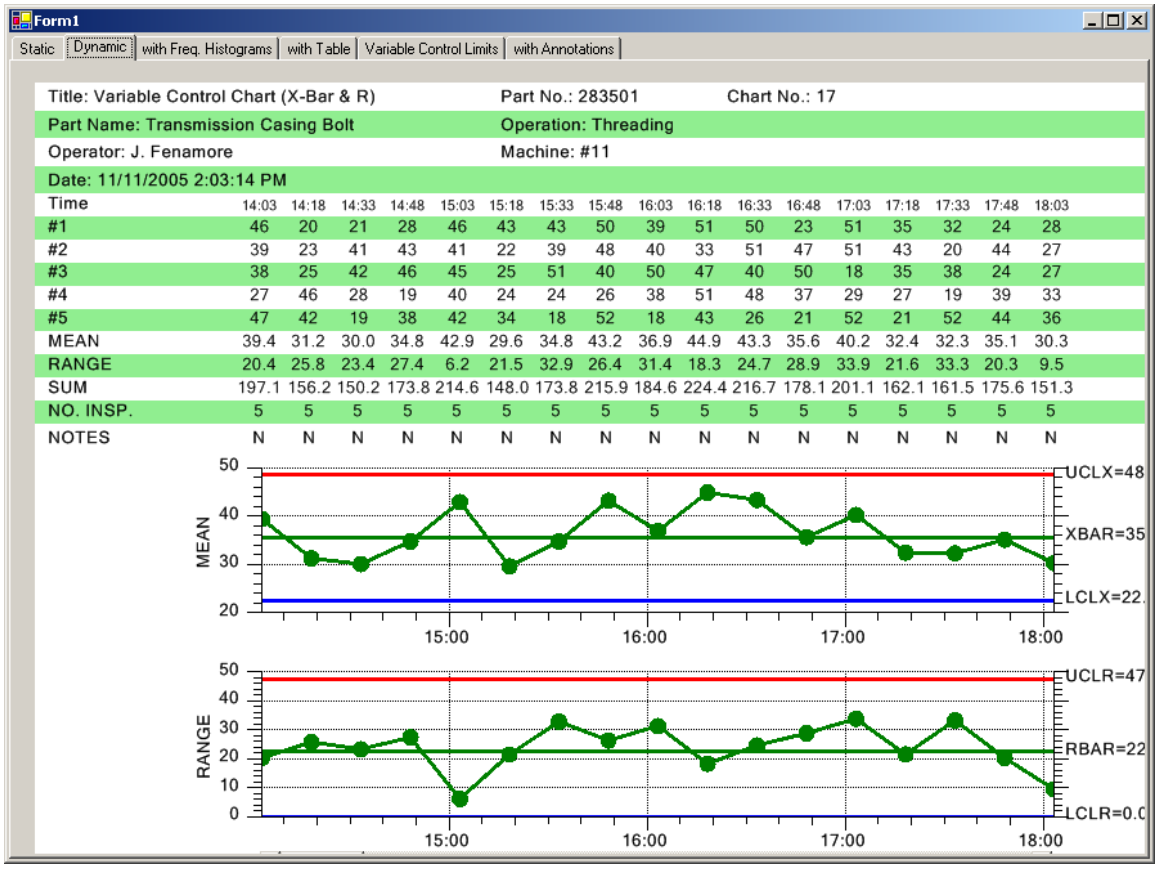
SPCArrayStatistics SPC involves many statistical calculations. The **SPCArrayStatistics** class includes routines for the calculation of sums, means, medians, ranges, minimum values, maximum values, variances, and standard deviations. It also includes routines for array sorting and calculating frequency bins for frequency histograms. It also includes functions that compute cumulative probability values for normal, Poisson, and chi-squared distributions.

SPCControlParameters

The **SPCControlParameters** class contains the factors and formulas for calculating SPC control chart limits for *Variable* and *Attribute Control Charts*. It includes calculations for the most common SPC charts: X-Bar R, Median and Range, X-Bar Sigma, X-R, u-chart, p-chart, np-chart, and c-chart.

Tabular Display

Table Display of Sampled and Calculated SPC Control Chart Value



SPCGeneralizedTableDisplay

The **SPCGeneralizedTableDisplay** manages a list of **ChartText** objects (**NumericLabel**, **StringLabel** and **TimeLabel** objects), that encapsulate each unique table entry in the SPC chart table. This class also manages the spacing between the rows and columns of the table, and the alternating stripe used as a background for the table.

SPC Control Alarms

SPCControlLimitAlarmArgs

This class passes event information to a **SPCControlLimitAlarmEventDelegate** alarm processing delegate.

SPCControlLimitAlarmEventDelegate

A delegate type for hooking up control limit alarm notifications

4. QCChart2D for .*Net* Class Summary

This chapter is a summary of the information in the **QCChart2DNetManual** PDF file. It is not meant to replace that information. Refer to that manual for detailed information concerning these classes.

QCChart2D for .*Net* Class Summary

The following categories of classes realize these design considerations.

Chart view class	The chart view class is a **UserControl** subclass that manages the graph objects placed in the graph
Data classes	There are data classes for simple xy and group data types. There are also data classes that handle **System.DateTime** date/time data and contour data.
Scale transform classes	The scale transform classes handle the conversion of physical coordinate values to working coordinate values for a single dimension.
Coordinate transform classes	The coordinate transform classes handle the conversion of physical coordinate values to working coordinate values for a parametric (2D) coordinate system.
Attribute class	The attribute class encapsulates the most common attributes (line color, fill color, line style, line thickness, etc.) for a chart object.
Auto-Scale classes	The coordinate transform classes use the auto-scale classes to establish the minimum and maximum values used to scale a 2D coordinate system. The axis classes also use the auto-scale classes to establish proper tick mark spacing values.
Charting object classes	The chart object classes includes all objects placeable in a chart. That includes axes, axes labels, plot objects (line plots, bar graphs, scatter plots, etc.), grids, titles, backgrounds, images and arbitrary shapes.
Mouse interaction classes	These classes, directly and indirectly **System.EventHandler** delegates that trap mouse events and permit the user to create and move data cursors,

	move plot objects, display tooltips and select data points in all types of graphs.
File and printer rendering	These classes render the chart image to a printer, to a variety of file formats including JPEG, and BMP, or to a .Net **Image** object.
Miscellaneous utility classes	Other classes use these for data storage, file I/O, and data processing.

A summary of each category appears in the following section.

Chart Window Classes

System.Windows.Forms.UserControl
- **ChartView**

The starting point of a chart is the **ChartView** class. The **ChartView** class derives from the .Net **System.Windows.Forms.UserControl** class**,** where the **UserControl** class is the base class for the .Net collection of standard components such as menus, buttons, check boxes, etc. The **ChartView** class manages a collection of chart objects in a chart and automatically updates the chart objects when the underlying window processes a paint event. Since the **ChartView** class is a subclass of the **UserControl** class, it acts as a container for other .Net components too.

Data Classes

ChartDataset
- **SimpleDataset**
  - **TimeSimpleDataset**
  - **ElapsedTimeSimpleDataset**
  - **ContourDataset**
- **GroupDataset**
  - **TimeGroupDataset**
  - **ElapsedTimeGroupDataset**

The dataset classes organize the numeric data associated with a plotting object. There are two major types of data supported by the **ChartDataset** class. The first is simple xy data,

where for every x-value there is one y-value. The second data type is group data, where every x-value can have one or more y-values.

ChartDataset The abstract base class for the other dataset classes. It contains data common to all of the dataset classes, such as the x-value array, the number of x-values, the dataset name and the dataset type.

SimpleDataset	Represents simple xy data, where for every x-value there is one y-value.
TimeSimpleDataset	A subclass of **SimpleDataset**, it is initialized using **ChartCalendar** dates (a wrapper around the System.DateTime value class) in place of the x- or y-values.
ElapsedTimeSimpleDataset	A subclass of **SimpleDataset**, it is initialized with **TimeSpan** objects, or milliseconds, in place of the x- or y-values.
ContourDataset	A subclass of **SimpleDataset**, it adds a third dimension (z-values) to the x- and y- values of the simple dataset.
GroupDataset	Represents group data, where every x-value can have one or more y-values.
TimeGroupDataset	A subclass of **GroupDataset**, it uses **ChartCalendar** dates (a wrapper around the System.DateTime value class) as the x-values, and floating point numbers as the y-values.
ElapsedTimeGroupDataset	A subclass of **GroupDataset**, it uses **TimeSpan** objects, or milliseconds, as the x-values, and floating point numbers as the y-values.

Scale Classes

ChartScale

- **LinearScale**
- **LogScale**
- **TimeScale**
- **ElapsedTimeScale**

The **ChartScale** abstract base class defines coordinate transformation functions for a single dimension. It is useful to be able to mix and match different scale transform functions for x- and y-dimensions of the **PhysicalCoordinates** class. The job of a **ChartScale** derived object is to convert a dimension from the current *physical* coordinate system into the current *working* coordinate system.

LinearScale	A concrete implementation of the **ChartScale** class. It converts a linear physical coordinate system into the working coordinate system.
LogScale	A concrete implementation of the **ChartScale** class. It converts a logarithmic physical coordinate system into the working coordinate system.
TimeScale	A concrete implementation of the **ChartScale** class. converts a date/time physical coordinate system into the working coordinate system.
ElapsedTimeScale	A concrete implementation of the **ChartScale** class. converts an elapsed time coordinate system into the working coordinate system.

Coordinate Transform Classes

UserCoordinates
- **WorldCoordinates**
  - **WorkingCoordinates**
    - **PhysicalCoordinates**
      - **CartesianCoordinates**
        - **ElapsedTimeCoordinates**
        - **PolarCoordinates**
        - **AntennaCoordinates**
      - **TimeCoordinates**

The coordinate transform classes maintain a 2D coordinate system. Many different coordinate systems are used to position and draw objects in a graph. Examples of some of the coordinate systems include the device coordinates of the current window, normalized coordinates for the current window and plotting area, and scaled physical coordinates of the plotting area.

UserCoordinates	This class manages the interface to the **System.Drawing** classes and contains routines for drawing lines, rectangles and text using .Net device coordinates.
WorldCoordinates	This class derives from the **UserCoordinates** class and maps a device independent world coordinate system on top of the .Net device coordinate system.
WorkingCoordinates	This class derives from the **WorldCoordinates** class and extends the physical coordinate system of the *plot area* (the area typically bounded by the charts axes) to include the complete *graph area* (the area of the chart outside of the *plot area*).
PhysicalCoordinates	This class is an abstract base class derived from **WorkingCoordinates** and defines the routines needed to map the physical coordinate system of a plot area into a working coordinate system. Different scale objects (**ChartScale** derived) are installed for converting physical x- and y-coordinate values into working coordinate values.
CartesianCoordinates	This class is a concrete implementation of the **PhysicalCoordinates** class and implements a coordinate system used to plot linear, logarithmic and semi-logarithmic graphs.
TimeCoordinates	This class is a concrete implementation of the **PhysicalCoordinates** class and implements a coordinate system used to plot **GregorianCalenar** time-based data.
ElapsedTimeCoordinates	This class is a subclass of the **CartesianCoordinates** class and implements a coordinate system used to plot elapsed time data.
PolarCoordinates	This class is a subclass of the **CartesianCoordinates** class and implements a coordinate system used to plot polar coordinate data.
AntennaCoordinates	This class is a subclass of the **CartesianCoordinates** class and implements a coordinate system used to plot antenna coordinate data. The antenna coordinate system differs from the more common polar coordinate system in that the radius can have plus/minus values, the angular values are in

degrees, and the angular values increase in the clockwise direction.

Attribute Class

ChartAttribute
ChartGradient

This class consolidates the common line and fill attributes as a single class. Most of the graph objects have a property of this class that controls the color, line thickness and fill attributes of the object. The **ChartGradient** class expands the number of color options available in the **ChartAttribute** class.

ChartAttribute	This class consolidates the common line and fill attributes associated with a **GraphObj** object into a single class.
ChartGradient	A **ChartGradient** can be added to a **ChartAttribute** object, defining a multicolor gradient that is applied wherever the color fill attribute is normally used

Auto-Scaling Classes

AutoScale
- **LinearAutoScale**
- **LogAutoScale**
- **TimeAutoScale**
- **ElapsedTimeAutoScale**

Usually, programmers do not know in advance the scale for a chart. Normally the program needs to analyze the current data for minimum and maximum values and create a chart scale based on those values. Auto-scaling, and the creation of appropriate axes, with endpoints at even values, and well-rounded major and minor tick mark spacing, is quite complicated. The **AutoScale** classes provide tools that make automatic generation of charts easier.

AutoScale	This class is the abstract base class for the auto-scale classes.
LinearAutoScale	This class is a concrete implementation of the **AutoScale** class. It calculates scaling values based on the numeric values in **SimpleDataset** and **GroupDataset** objects. Linear scales and axes use it for auto-scale calculations.
LogAutoScale	This class is a concrete implementation of the **AutoScale** class. It calculates scaling values based on the numeric values in **SimpleDataset** and **GroupDataset** objects. Logarithmic scales and axes use it for auto-scale calculations.
TimeAutoScale	This class is a concrete implementation of the **AutoScale** class. It calculates scaling values based on the **ChartCalendar** values in **TimeSimpleDataset** and **TimeGroupDataset** objects. Date/time scales and axes use it for auto-scale calculations.
ElapsedTimeAutoScale	This class is a concrete implementation of the **AutoScale** class. It calculates scaling values based on the numeric values in **ElapsedTimeSimpleDataset** and **ElapsedTimeGroupDataset** objects. The elapsed time classes use it for auto-scale calculations.

Chart Object Classes

Chart objects are graph objects that can be rendered in the current graph window. This is in comparison to other classes that are purely calculation classes, such as the coordinate conversion classes. All chart objects have certain information in common. This includes instances of **ChartAttribute** and **PhysicalCoordinates** classes. The **ChartAttribute** class contains basic color, line style, and gradient information for the object, while the **PhysicalCoordinates** maintains the coordinate system used by object. The majority of classes in the library derive from the **GraphObj** class, each class a specific charting object such as an axis, an axis label, a simple plot or a group plot. Add **GraphObj** derived objects (axes, plots, labels, title, etc.) to a graph using the **ChartView.AddChartObject** method.

GraphObj	This class is the abstract base class for all drawable graph objects. It contains information common to all chart objects. This class includes references to instances of the

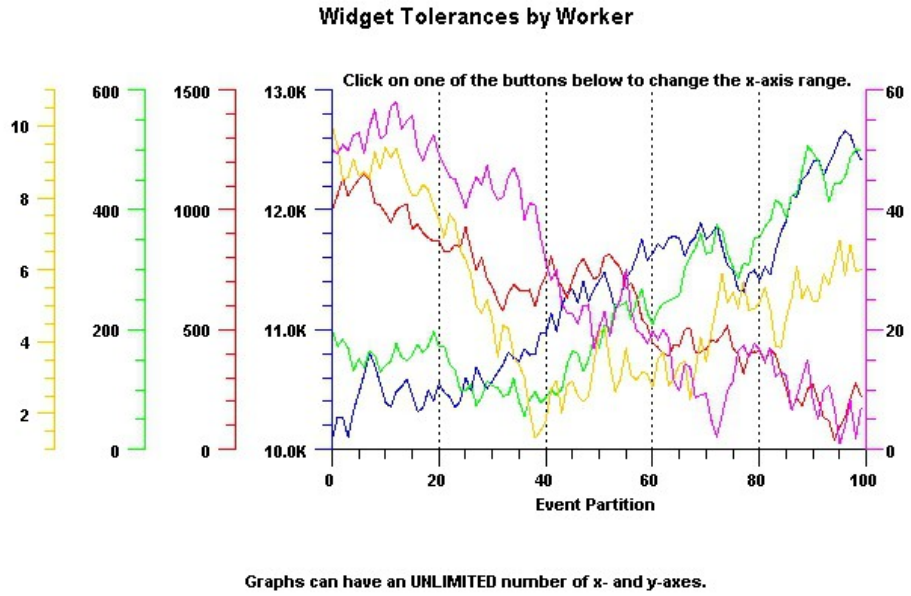
	ChartAttribute and **PhysicalCoordinates** classes. The **ChartAttribute** class contains basic color, line style, and gradient information for the object, while the **PhysicalCoordinates** maintains the coordinate system used by object. The majority of classes in the library derive from the **GraphObj** class, each class a specific charting object such as an axis, an axis label, a simple plot or a group plot
Background	This class fills the background of the entire chart, or the plot area of the chart, using a solid color, a color gradient, or a texture.

Axis Classes

Axis

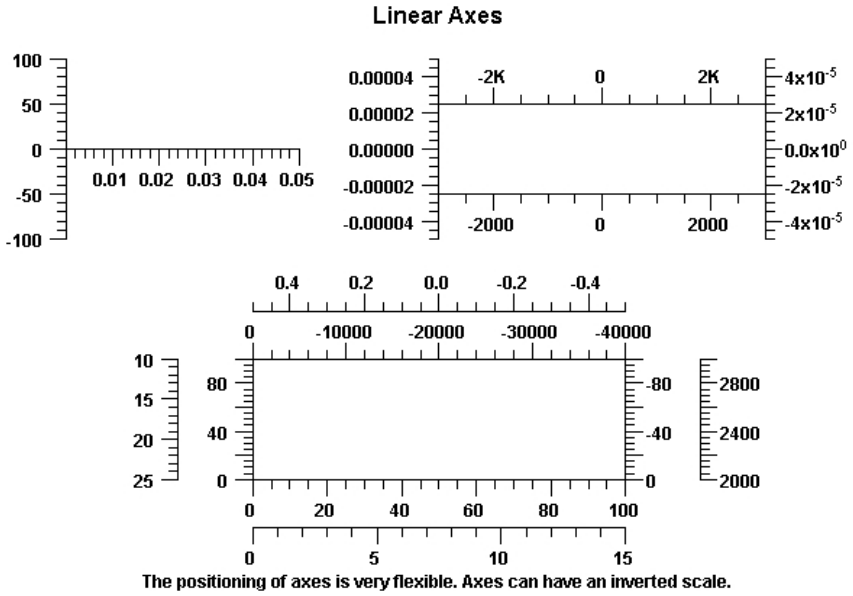
- **LinearAxis**
  - **PolarAxes**
  - **AntennaAxes**
  - **ElapsedTimeAxis**
- **LogAxis**
- **TimeAxis**

Creating a **PhysicalCoordinates** coordinate system does not automatically create a pair of x- and y-axes. Axes are separate charting objects drawn with respect to a specific **PhysicalCoordinates** object. The coordinate system and the axes do not need to have the same limits. In general, the limits of the coordinate system should be greater than or equal to the limits of the axes. The coordinate system may have limits of 0 to 15, while you may want the axes to extend from 0 to 10.


Widget Tolerances by Worker
Click on one of the buttons below to change the x-axis range.
Event Partition
Graphs can have an UNLIMITED number of x- and y-axes.

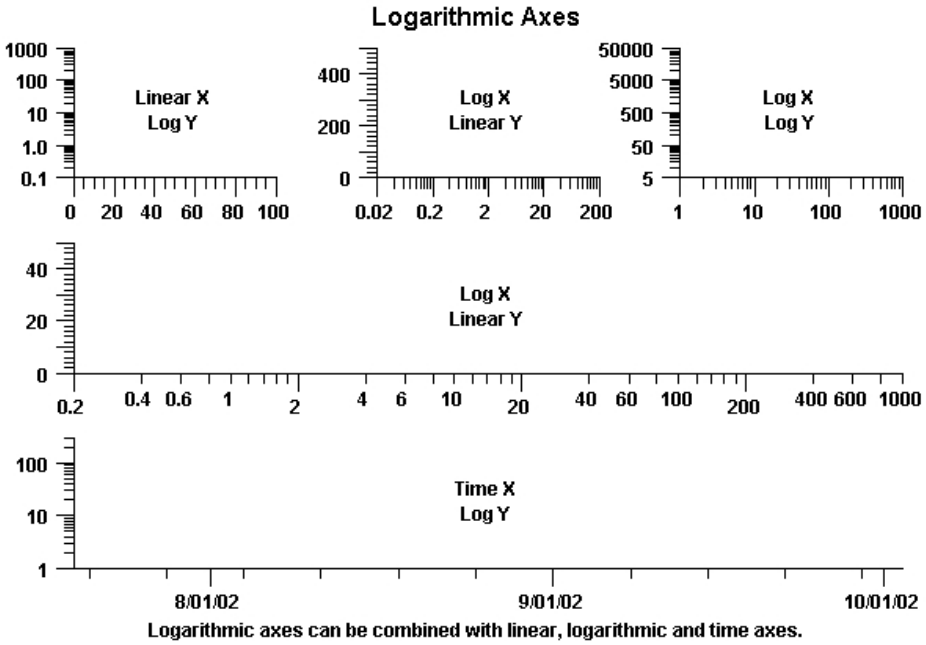
Axis

This class is the abstract base class for the other axis classes. It contains data and drawing routines common to all axis classes.



LinearAxis

This class implements a linear axis with major and minor tick marks placed at equally spaced intervals.

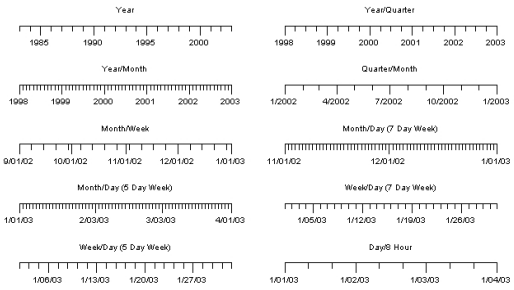


Logarithmic axes can be combined with linear, logarithmic and time axes.

LogAxis

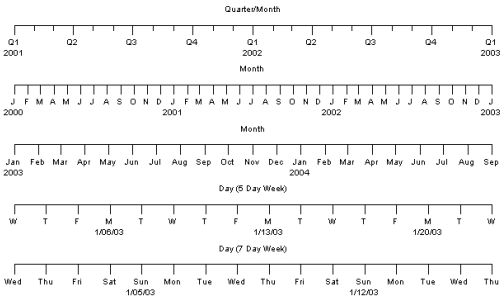
This class implements a logarithmic axis with major tick marks placed on logarithmic intervals, for example 1, 10,100 or 30, 300, 3000. The minor tick marks are placed within the major tick marks using linear intervals, for example 2, 3, 4, 5, 6, 7, 8, 9, 20, 30, 40, 50,.., 90. An important feature of the **LogAxis** class is that the major and minor tick marks do not have to fall on decade boundaries. A logarithmic axis must have a positive range exclusive of 0.0, and the tick marks can represent any logarithmic scale.

Date Axes



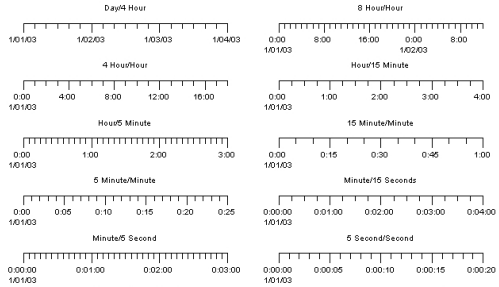
There are more than 40 different time/date axes types, appropriate for scales ranging from 1 second to 100 years.

Date Axes


Quarter/Month
Q1 Q2 Q3 Q4 Q1 Q2 Q3 Q4 Q1
2001 2002 2003
Month
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J
2000 2001 2002 2003
Month
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep
2003 2004
Day (5 Day Week)
W T F M T W T F M T W T F M T W
1/06/03 1/13/03 1/20/03
Day (7 Day Week)
Wed Thu Fri Sat Sun Mon Tue Wed Thu Fri Sat Sun Mon Tue Wed Thu
1/05/03 1/12/03

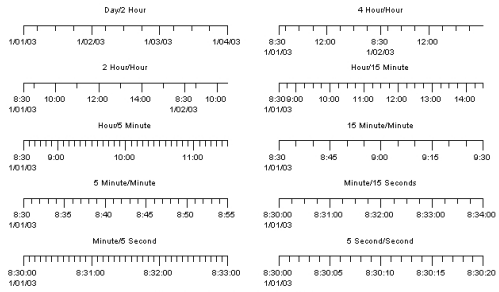
There are more than 40 different time/date axes types, appropriate for scales ranging from 1 second to 100 years.

Date Axes



There are more than 40 different time/date axes types, appropriate for scales ranging from 1 second to 100 years.

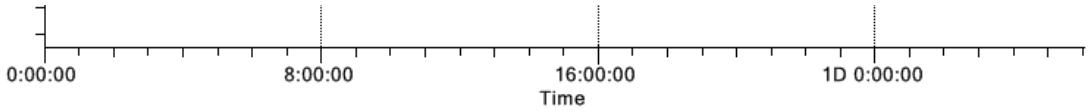
Time/Date Axes with Custom Hour Range (8:30 AM to 4:00 PM)



A time axis can be customized for non-24 hour range.

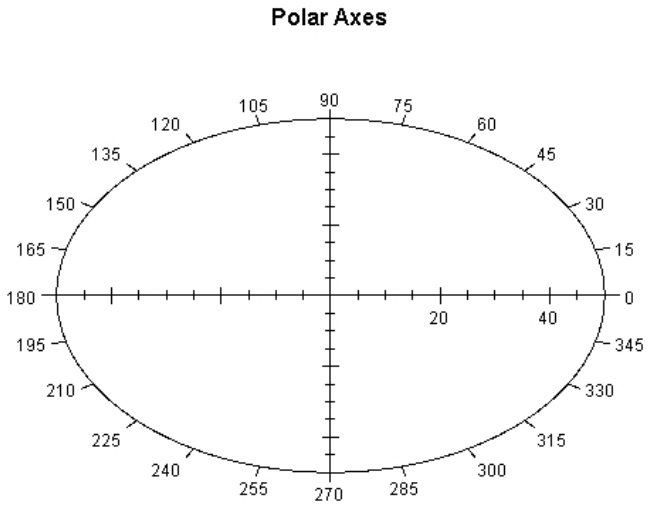
TimeAxis

This class is the most complex of the axis classes. It supports time scales ranging from 1 milliseond to hundreds of years. Dates and times are specified using the .Net **ChartCalendar** class. The major and minor tick marks can fall on any time base, where a time base represents seconds, minutes, hours, days, weeks, months or years. The scale can exclude weekends, for example, Friday, October 20, 2000 is immediately followed by Monday, October 23, 2000. A day can also have a custom range, for example a range of 9:30 AM to 4:00 PM. The chart time axis excludes time outside of this range. This makes the class very useful for the inter-day display of financial market information (stock, bonds, commodities, options, etc.) across several days, months or years.



ElapsedTimeAxis

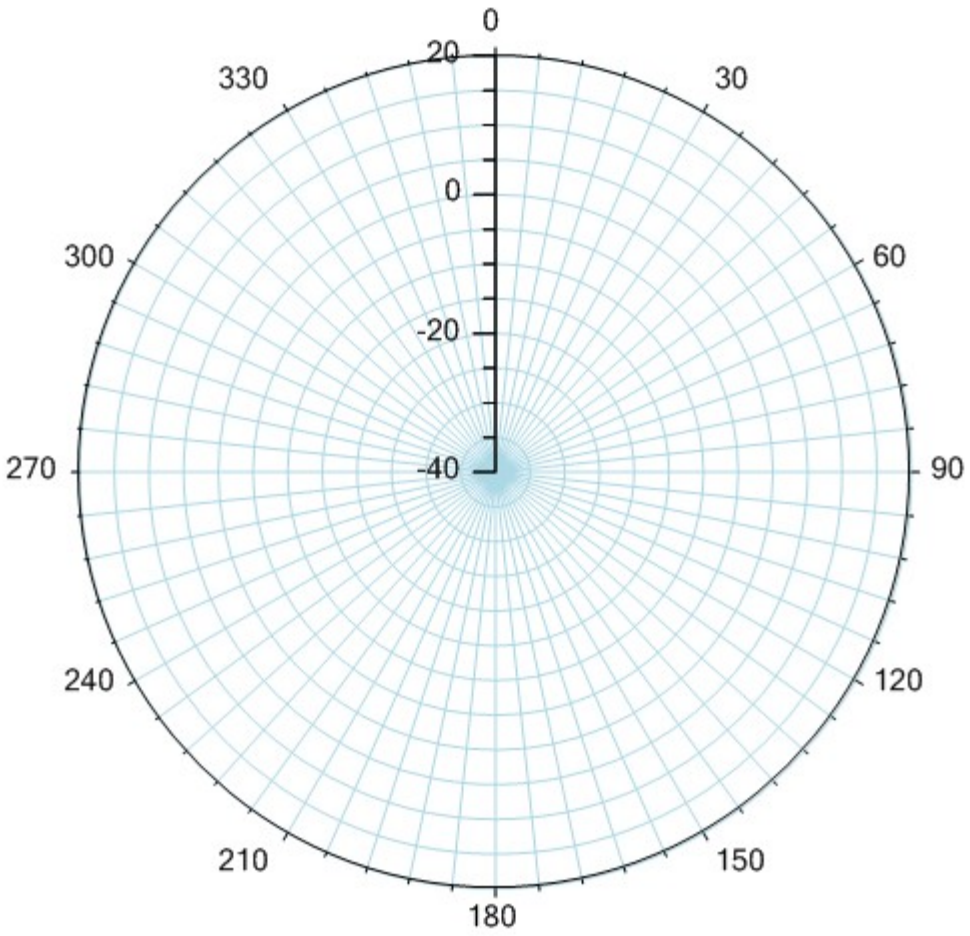
The elapsed time axis is very similar to the linear axis and is subclassed from that class. The main difference is the major and minor tick mark spacing calculated by the CalcAutoAxis method takes into account the base 60 of seconds per minute and minutes per hour, and the base 24 of hours per day. It is a continuous linear scale.



A polar axis consists of the x and y axis for magnitude, and the outer circle for the angle.

PolarAxes

This class has three separate axes: two linear and one circular. The two linear axes, scaled for +- the magnitude of the polar scale, form a cross with the center of both axes at the origin (0, 0. The third axis is a circle centered on the origin with a radius equal to the magnitude of the polar scale. This circular axis represents 360 degrees (or 2 Pi radians) of the polar scale and the tick marks that circle this axis are spaced at equal degree intervals.



AntennaAxes This class has two axes: one linear y-axis and one circular axis. The linear axis is scaled for the desired range of radius values. This can extend from minus values to plus values. The second axis is a circle centered on the origin with a radius equal to the range of the radius scale. This circular axis represents 360 degrees of the antenna scale and the tick marks that circle this axis are spaced at equal degree intervals.

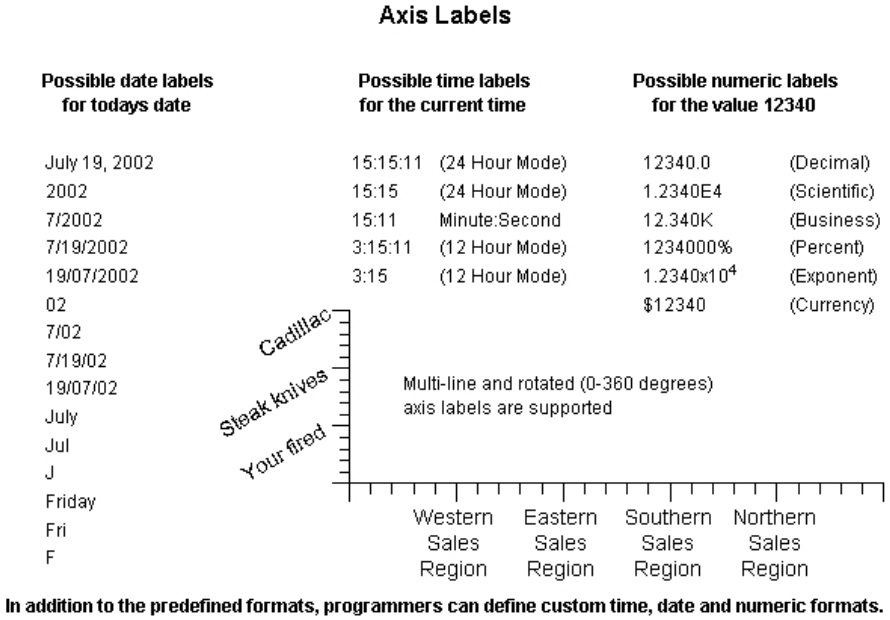
Axis Label Classes

AxisLabels

- **NumericAxisLabels**
- **StringAxisLabels**
- **PolarAxesLabels**
- **AntennaAxesLabels**

TimeAxisLabels
ElapsedTimeAxisLabels

Axis labels inform the user of the x- and y-scales used in the chart. The labels center on the major tick marks of the associated axis. Axis labels are usually numbers, times, dates, or arbitrary strings.



AxisLabels — This class is the abstract base class for all axis label objects. It places numeric labels, date/time labels, or arbitrary text labels, at the major tick marks of the associated axis object. In addition to the standard font options (type, size, style, color, etc.), axis label text can be rotated 360 degrees in one degree increments.

NumericAxisLabels — This class labels the major tick marks of the **LinearAxis**, and **LogAxis** classes. The class supports many predefined and user-definable formats, including numeric, exponent, percentage, business and currency formats.

StringAxisLabels — This class labels the major tick marks of the **LinearAxis**, and **LogAxis** classes using user-defined strings.

TimeAxisLabels	This class labels the major tick marks of the associated **TimeAxis** object. The class supports many time (23:59:59) and date (5/17/2001) formats. It is also possible to define custom date/time formats.
ElapsedTimeAxisLabels	This class labels the major tick marks of the associated **ElapsedTimeAxis** object. The class supports HH:MM:SS and MM:SS formats, with decimal seconds out to 0.00001, i.e. "12:22:43.01234". It also supports a cumulative hour format (101:51:22), and a couple of day formats (4.5:51:22, 4D 5:51:22).
PolarAxesLabels	This class labels the major tick marks of the associated **PolarAxes** object. The x-axis is labeled from 0.0 to the polar scale magnitude, and the circular axis is labeled counter clockwise from 0 to 360 degrees, starting at 3:00.
AntennaAxesLabels	This class labels the major tick marks of the associated **AntennaAxes** object. The y-axis is labeled from the radius minimum to the radius maximum. The circular axis is labeled clockwise from 0 to 360 degrees, starting at 12:00.

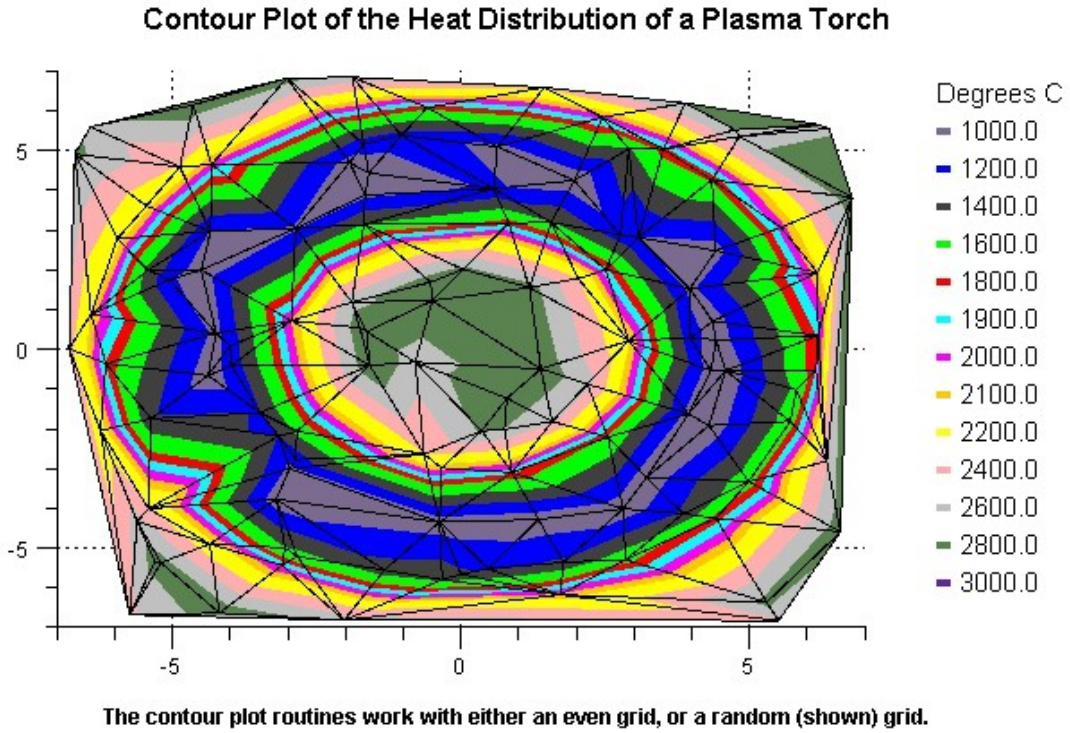
Chart Plot Classes

ChartPlot
- **ContourPlot**
- **GroupPlot**
- **PieChart**
- **PolarPlot**
- **AntennaPlot**
- **SimplePlot**

Plot objects are objects that display data organized in a **ChartDataset** class. There are six main categories: simple, group, polar, antenna, contour and pie plots. Simple plots graph data organized as a simple set of xy data points. The most common examples of simple plots are line plots, bar graphs, scatter plots and line-marker plots. Group plots graph data organized as multiple y-values for each x-value. The most common examples of group plots are stacked bar graphs, open-high-low-close plots, candlestick plots, floating stacked bar plots and "box and whisker" plots. Polar charts plot data organized as a simple set of data points, where each data point represents a polar magnitude and angle pair, rather than xy Cartesian coordinate values. The most common example of polar charts is the display of complex numbers (a + b*i*), and it is used in many engineering

disciplines. Antenna charts plot data organized as a simple set of data points, where each data point represents a radius value and angle pair, rather than xy Cartesian coordinate values. The most common example of antenna charts is the display of antenna performance and specification graphs. The contour plot type displays the iso-lines, or contours, of a 3D surface using either lines or regions of solid color. The last plot object category is the pie chart, were a pie wedge represents each data value. The size of the pie wedge is proportional to the fraction (data value / sum of all data values).

ChartPlot This class is the abstract base class for chart plot objects. It contains a reference to a **ChartDataset** derived class containing the data associated with the plot.



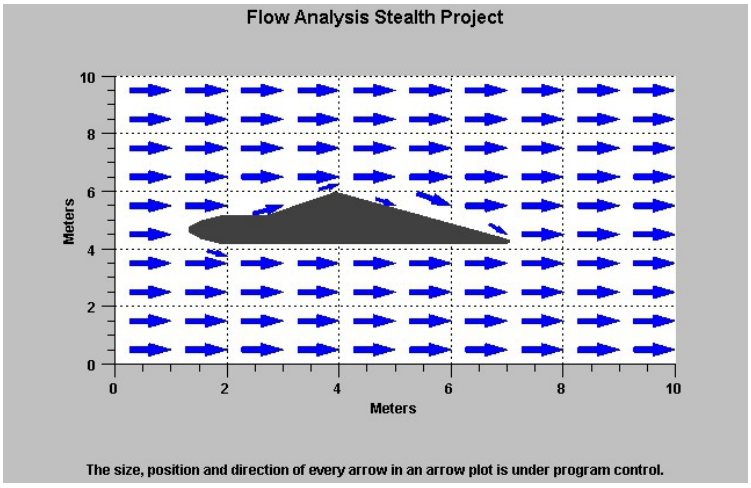
ContourPlot This class is a concrete implementation of the **ChartPlot** class and displays a contour plot using either lines, or regions filled with color.

Group Plot Classes

GroupPlot
- **ArrowPlot**
- **BoxWhiskerPlot**
- **BubblePlot**
- **CandlestickPlot**
- **CellPlot**
- **ErrorBarPlot**
- **FloatingBarPlot**
- **FloatingStackedBarPlot**
- **GroupBarPlot**
- **GroupVersaPlot**
- **HistogramPlot**
- **LineGapPlot**
- **MultiLinePlot**
- **OHLCPlot**
- **StackedBarPlot**
- **StackedLinePlot**
- **GroupVeraPlot**

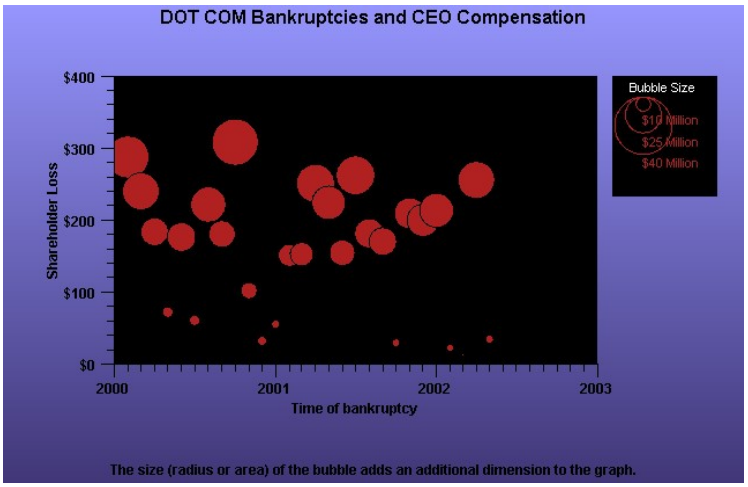
Group plots use data organized as arrays of x- and y-values, where there is one or more y for every x.. Group plot types include multi-line plots, stacked line plots, stacked bar plots, group bar plots, error bar plots, floating bar plots, floating stacked bar plots, open-high-low-close plots, candlestick plots, arrow plots, histogram plots, cell plots, “box and whisker” plots, and bubble plots.

GroupPlot This class is an abstract base class for all group plot classes.



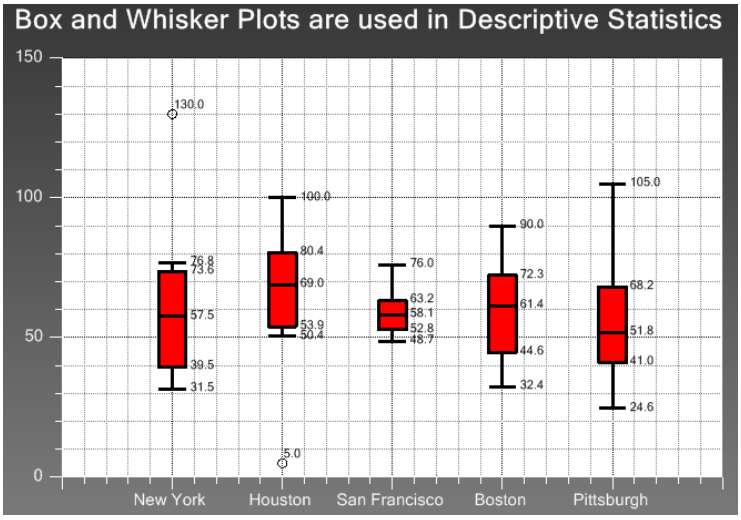
ArrowPlot

This class is a concrete implementation of the **GroupPlot** class and it displays a collection of arrows as defined by the data in a group dataset. The position, size, and rotation of each arrow in the collection is independently controlled



BubblePlot

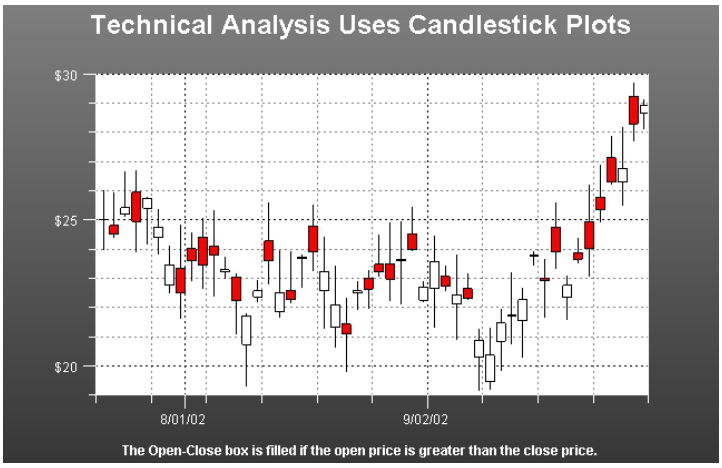
This class is a concrete implementation of the **GroupPlot** class and displays bubble plots. The values in the dataset specify the position and size of each bubble in a bubble chart.



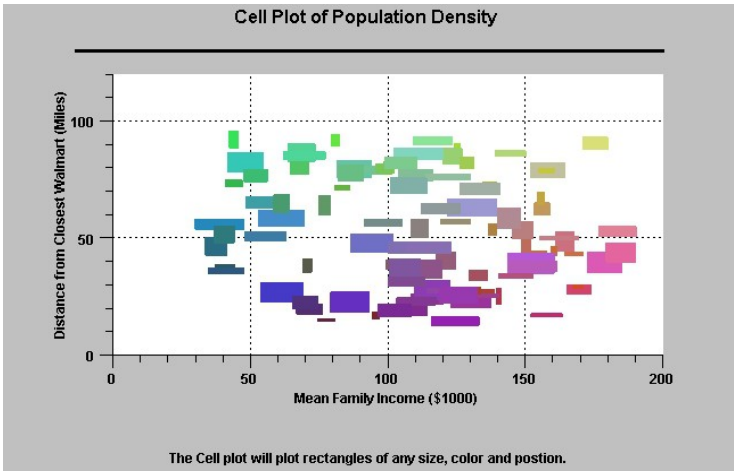
BoxWhiskerPlot

This class is a concrete implementation of the **GroupPlot** class and displays box and whisker plots. The BoxWhiskerPlot class graphically depicts groups of numerical data through their five-number summaries (the

smallest observation, lower quartile (Q1), median (Q2), upper quartile (Q3), and largest observation).



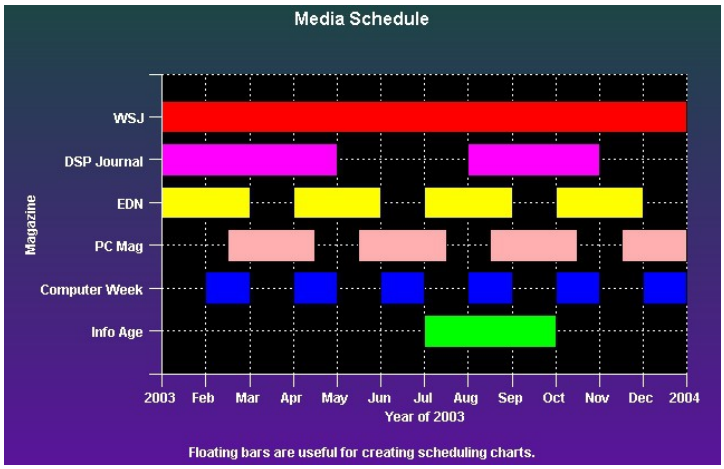
CandlestickPlot This class is a concrete implementation of the **GroupPlot** class and displays stock market data in an open-high-low-close format common in financial technical analysis.



CellPlot This class is a concrete implementation of the **GroupPlot** class and displays cell plots. A cell plot is a collection of rectangular objects with independent positions, widths and heights, specified using the values of the associated group dataset.

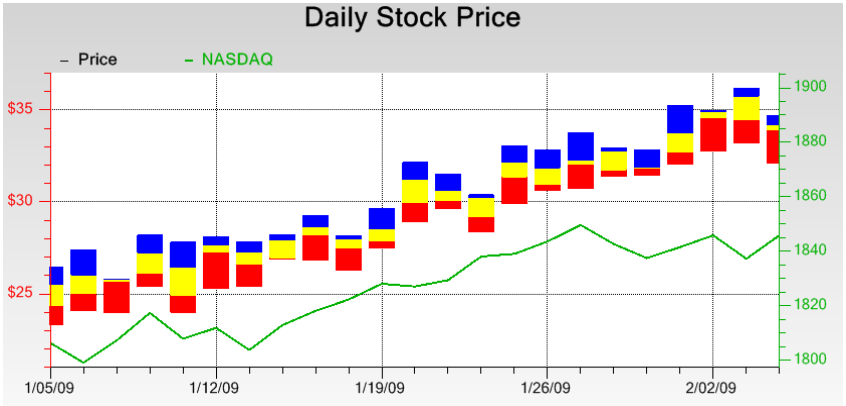
ErrorBarPlot

This class is a concrete implementation of the **GroupPlot** class and displays error bars. Error bars are two lines positioned about a data point that signify the statistical error associated with the data point



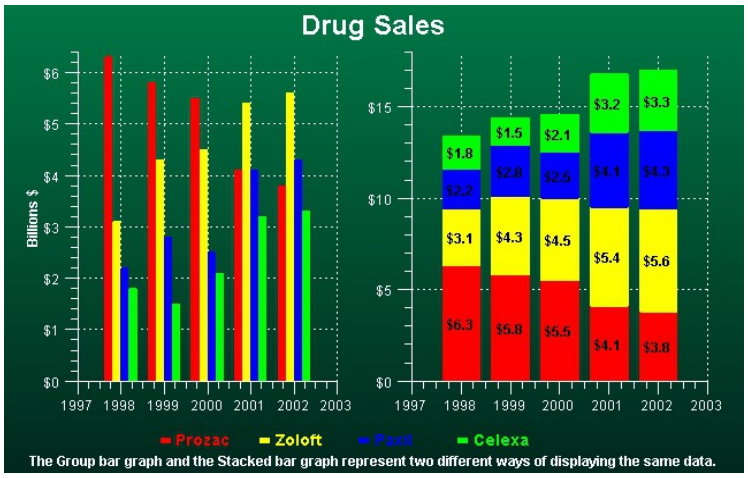
FloatingBarPlot

This class is a concrete implementation of the **GroupPlot** class and displays free-floating bars in a graph. The bars are free floating because each bar does not reference a fixed base value, as do simple bar plots, stacked bar plots and group bar plots.



FloatingStackedBarPlot

This class is a concrete implementation of the **GroupPlot** class and displays free-floating stacked bars. The bars are free floating because each bar does not reference a fixed base value, as do simple bar plots, stacked bar plots and group bar plots.



GroupBarPlot

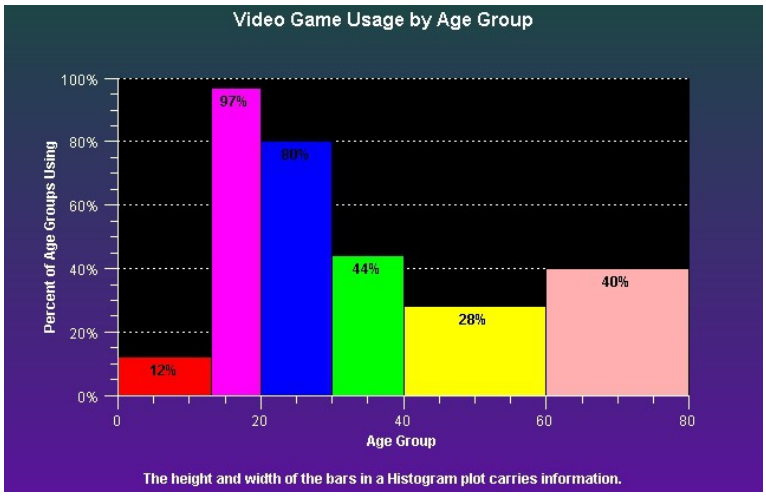
This class is a concrete implementation of the **GroupPlot** class and displays group data in a group bar format. Individual bars, the height of which corresponds to the group y-values of the dataset, display side by side, as a group, justified with respect to the x-position value for each group. The group bars share a common base value.

StackedBarPlot

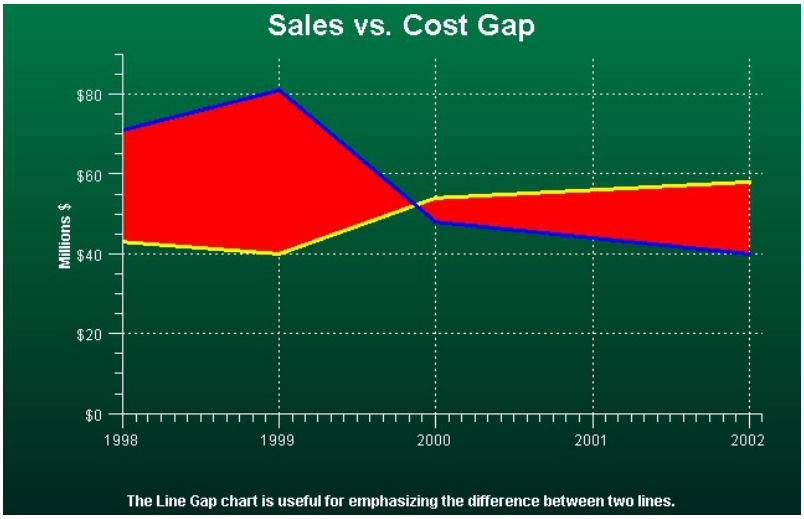
This class is a concrete implementation of the **GroupPlot** class and displays data as stacked bars. In a stacked bar plot each group is stacked on top of one another, each group bar a cumulative sum of the related group items before it.

GroupVeraPlot

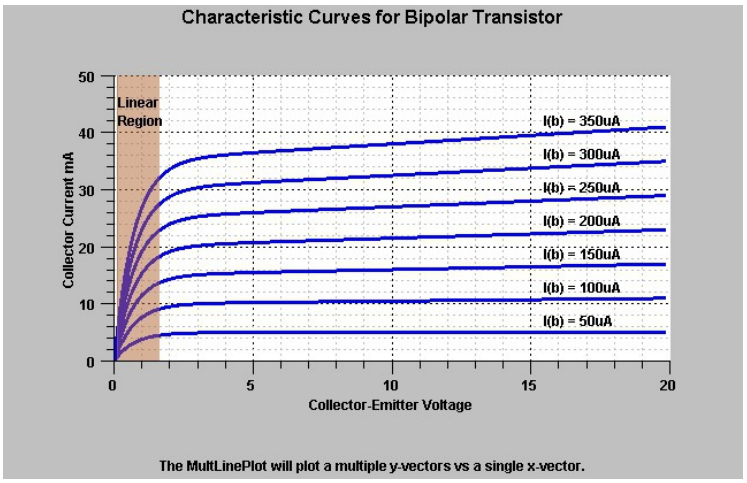
The **GroupVersaPlot** is a plot type that can be any of the eight group plot types: GROUPBAR, STACKEDBAR, CANDLESTICK, OHLC, MULTILINE, STACKEDLINE, FLOATINGBAR and FLOATING_STACKED_BAR. Use it when you want to be able to change from one plot type to another, without deleting the instance of the old plot object and creating an instance of the new.



HistogramPlot This class is a concrete implementation of the **GroupPlot** class and displays histogram plots. A histogram plot is a collection of rectangular objects with independent widths and heights, specified using the values of the associated group dataset. The histogram bars share a common base value.

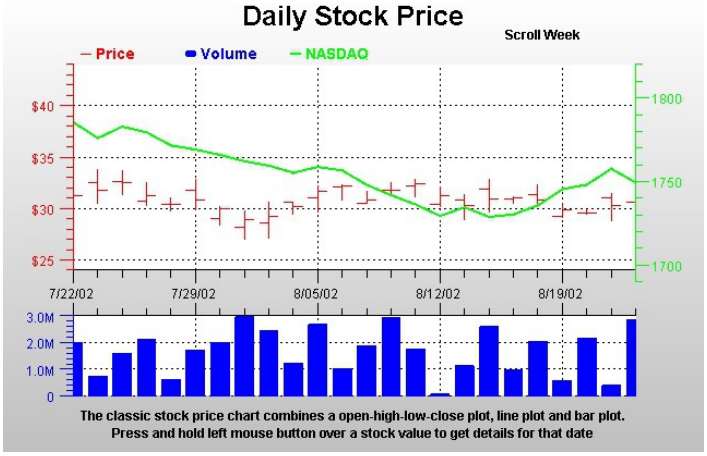


LineGapPlot This class is a concrete implementation of the **GroupPlot** class. A line gap chart consists of two lines plots where a contrasting color fills the area between the two lines, highlighting the difference.



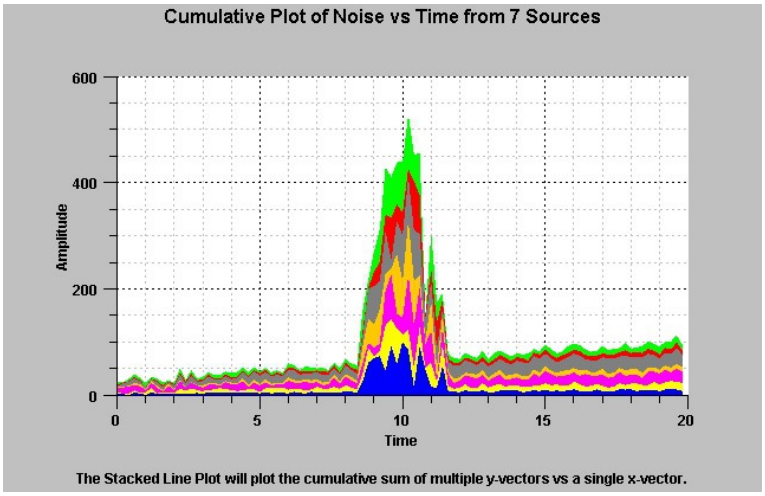
MultiLinePlot

This class is a concrete implementation of the **GroupPlot** class and displays group data in multi-line format. A group dataset with four groups will display four separate line plots. The y-values for each line of the line plot represent the y-values for each group of the group dataset. Each line plot share the same x-values of the group dataset.



OHLCPlot

This class is a concrete implementation of the **GroupPlot** class and displays stock market data in an open-high-low-close format common in financial technical analysis. Every item of the plot is a vertical line, representing High and Low values, with two small horizontal "flags", one left and one right extending from the vertical High-Low line and representing the Open and Close values.



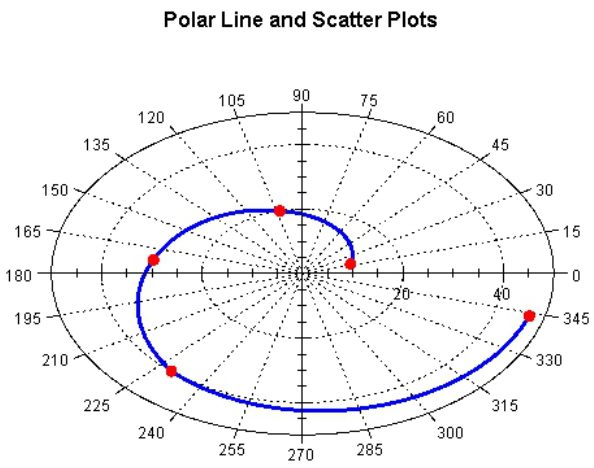
StackedLinePlot This class is a concrete implementation of the **GroupPlot** class and displays data in a stacked line format. In a stacked line plot each group is stacked on top of one another, each group line a cumulative sum of the related group items before it.

Polar Plot Classes

PolarPlot
- **PolarLinePlot**
- **PolarScatterPlot**

Polar plots that use data organized as arrays of x- and y-values, where an x-value represents the magnitude of a point in polar coordinates, and the y-value represents the angle, in radians, of a point in polar coordinates. Polar plot types include line plots and scatter plots.

PolarPlot This class is an abstract base class for the polar plot classes.



PolarLinePlot This class is a concrete implementation of the **PolarPlot** class and displays data in a simple line plot format. The lines drawn between adjacent data points use polar coordinate interpolation.

PolarScatterPlot This class is a concrete implementation of the **PolarPlot** class and displays data in a simple scatter plot format.

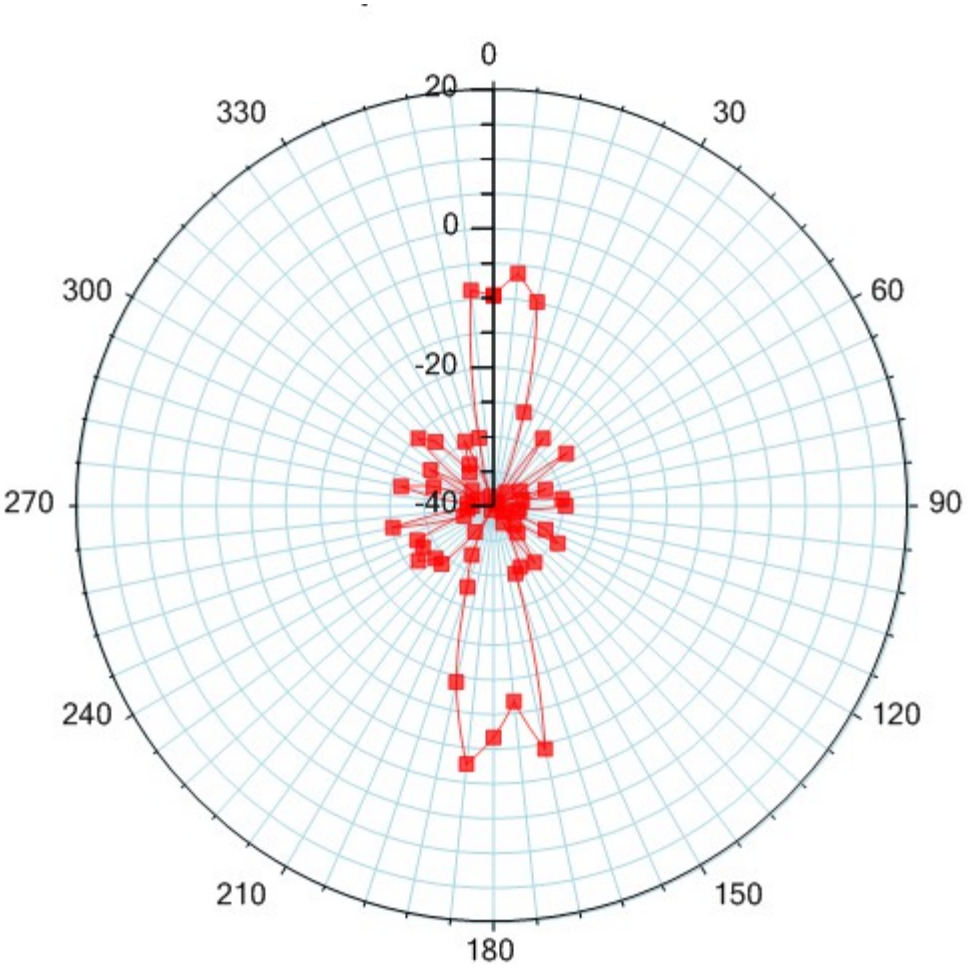
Antenna Plot Classes

AntennaPlot
- **AntennaLinePlot**
- **AntennaScatterPlot**
- **AntennaLineMarkerPlot**

GraphObj
- **AntennaAnnotation**

Antenna plots that use data organized as arrays of x- and y-values, where an x-value represents the radial value of a point in antenna coordinates, and the y-value represents the angle, in degrees, of a point in antenna coordinates. Antenna plot types include line plots, scatter plots, line marker plots, and an annotation class.

AntennaPlot This class is an abstract base class for the polar plot classes.



AntennaLineMarkerPlot

AntennaLinePlot This class is a concrete implementation of the **AntennaPlot** class and displays data in a simple line plot format. The lines drawn between adjacent data points use antenna coordinate interpolation.

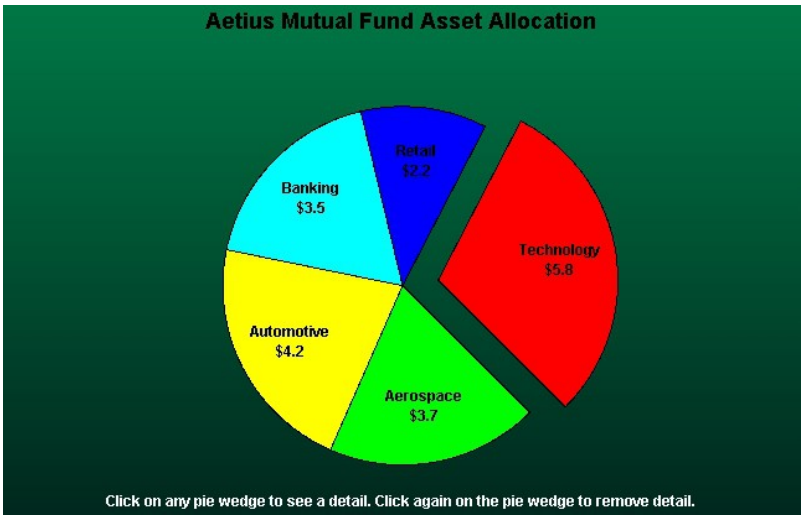
AntennaScatterPlot This class is a concrete implementation of the **AntennaPlot** class and displays data in a simple scatter plot format.

AntennaLineMarkerPlot This class is a concrete implementation of the **AntennaPlot** class and displays data in a simple line markder plot format.

AntennaAnnotation This class is used to highlight, or mark, a specific attribute of the chart. It can mark a constant radial value using a circle, or it can mark a constant angular value using a radial line from the origin to the outer edge of the scale.

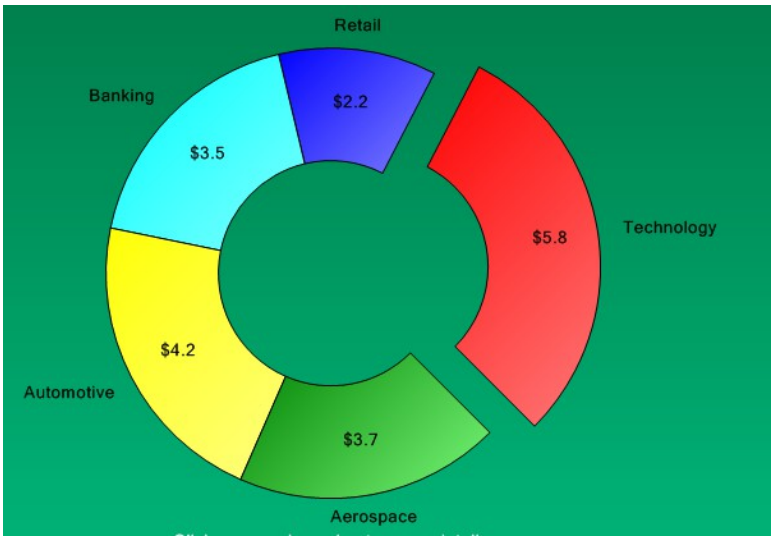
Pie and Ring Chart Classes

It uses data organized as arrays of x- and y-values, where an x-value represents the numeric value of a pie wedge, and a y-value specifies the offset (or "explosion") of a pie wedge with respect to the center of the pie.



PieChart

The pie chart plots data in a simple pie chart format. It uses data organized as arrays of x- and y-values, where an x-value represents the numeric value of a pie wedge, and a y-value specifies the offset (or "explosion") of a pie wedge with respect to the center of the pie.



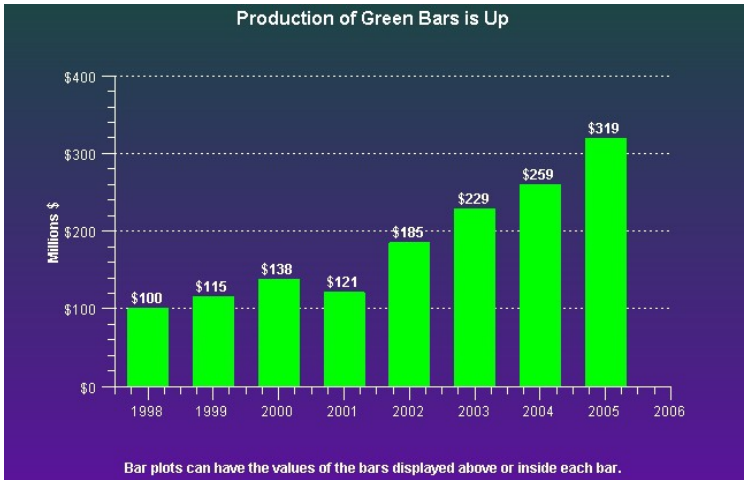
RingChart The ring chart plots data in a modified pie chart format known as a ring chartt. It uses data organized as arrays of x- and y-values, where an x-value represents the numeric value of a ring segment, and a y-value specifies the offset (or "explosion") of a ring segment with respect to the origin of the ring.

Simple Plot Classes

SimplePlot
- **SimpleBarPlot**
- **SimpleLineMarkerPlot**
- **SimpleLinePlot**
- **SimpleScatterPlot**
- **SimpleVeraPlot**

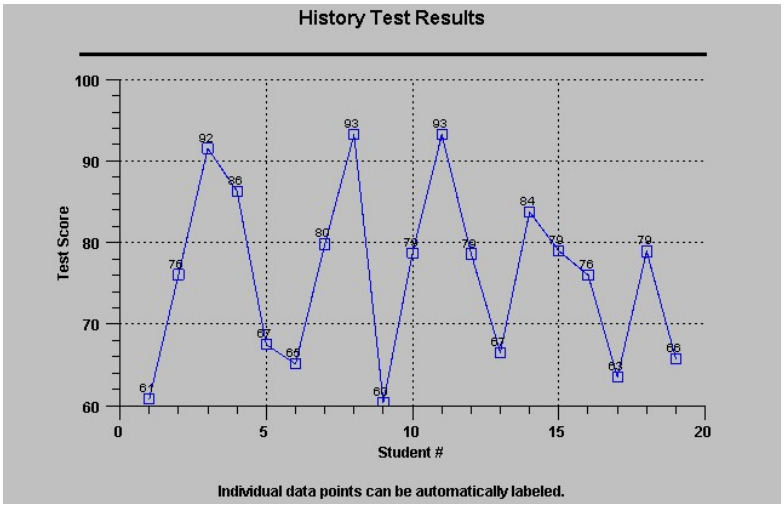
Simple plots use data organized as a simple array of xy points, where there is one y for every x. Simple plot types include line plots, scatter plots, bar graphs, and line-marker plots.

SimplePlot This class is an abstract base class for all simple plot classes.



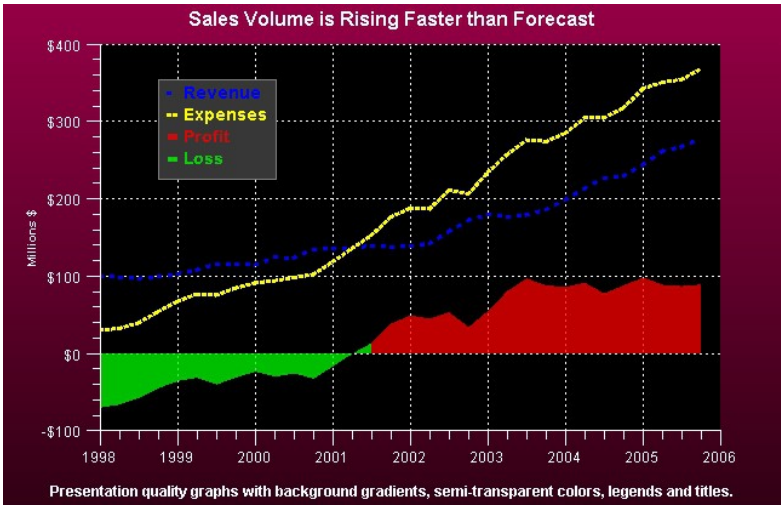
SimpleBarPlot This class is a concrete implementation of the **SimplePlot** class and displays data in a bar format. Individual bars, the

maximum value of which corresponds to the y-values of the dataset, are justified with respect to the x-values.

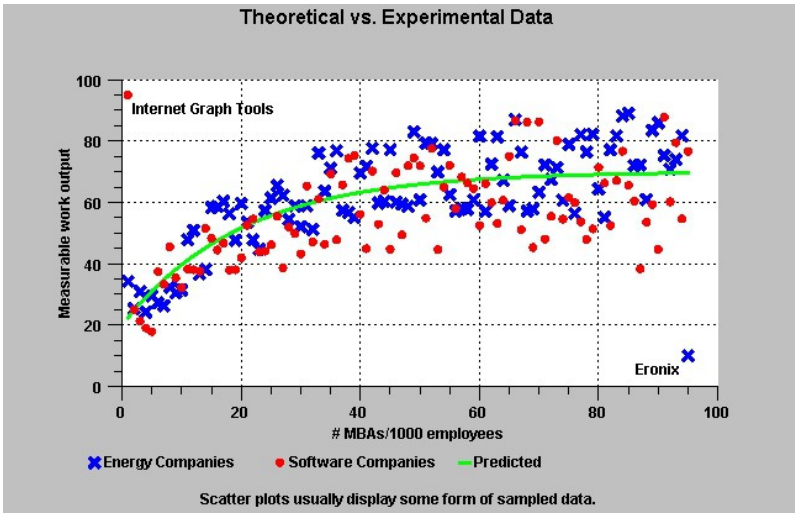


SimpleLineMarkerPlot

This class is a concrete implementation of the **SimplePlot** class and it displays simple datasets in a line plot format where scatter plot symbols highlight individual data points.



SimpleLinePlot This class is a concrete implementation of the **SimplePlot** class it displays simple datasets in a line plot format. Adjacent data points are connected using a straight, or a step line.



SimpleScatterPlot This class is a concrete implementation of the **SimplePlot** class and it displays simple datasets in a scatter plot format where each data point is represented using a symbol.

SimpleVersaPlot The **SimpleVersaPlot** is a plot type that can be any of the four simple plot types: LINE_MARKER_PLOT, LINE_PLOT, BAR_PLOT, SCATTER_PLOT. It is used when you want to be able to change from one plot type to another, without deleting the instance of the old plot object and creating an instance of the new.

Legend Classes

LegendItem
BubblePlotLegendItem
Legend
- **StandardLegend**
- **BubblePlotLegend**

Legends provide a key for interpreting the various plot objects in a graph. It organizes a collection of legend items, one for each plot objects in the graph, and displays them in a rectangular frame.

Legend	This class is the abstract base class for chart legends.
LegendItem	This class is the legend item class for all plot objects except for bubble plots. Each legend item manages one symbol and descriptive text for that symbol. The **StandardLegend** class uses objects of this type as legend items.
BubblePlotLegendItem	This class is the legend item class for bubble plots. Each legend item manages a circle and descriptive text specifying the value of a bubble of this size. The **BubblePlotLegend** class uses objects of this type as legend items.
StandardLegend	This class is a concrete implementation of the **Legend** class and it is the legend class for all plot objects except for bubble plots. The legend item objects display in a row or column format. Each legend item contains a symbol and a descriptive string. The symbol normally associates the legend item to a particular plot object, and the descriptive string describes what the plot object represents.
BubblePlotLegend	This class is a concrete implementation of the **Legend** class and it is a legend class used exclusively with bubble plots. The legend item objects display as offset, concentric circles with descriptive text giving the key for the value associated with a bubble of this size.

Grid Classes

Grid

PolarGrid
AntennaGrid

Grid lines are perpendicular to an axis, extending the major and/or minor tick marks of the axis across the width or height of the plot area of the chart.

Grid	This class defines the grid lines associated with an axis. Grid lines are perpendicular to an axis, extending the major and/or minor tick marks of the axis across the width or

height of the plot area of the chart. This class works in conjunction with the **LinearAxis**, **LogAxis** and **TimeAxis** classes.

PolarGrid This class defines the grid lines associated with a polar axis. A polar chart grid consists of two sets of lines. The first set is a group of concentric circles, centered on the origin and passing through the major and/or minor tick marks of the polar magnitude horizontal and vertical axes. The second set is a group of radial lines, starting at the origin and extending to the outermost edge of the polar plot circle, passing through the major and minor tick marks of the polar angle circular axis. This class works in conjunction with the **PolarAxes** class.

AntennaGrid Analogous to the **PolarGrid**, this class draws radial, and circular grid lines for an Antenna chart.

Chart Text Classes

ChartText
- **ChartTitle**
- **AxisTitle**
- **ChartLabel**
  - **NumericLabel**
  - **TimeLabel**
  - **StringLabel**
  - **ElapsedTimeLabel**

The chart text classes draw one or more strings in the chart window. Different classes support different numeric formats, including floating point numbers, date/time values and multi-line text strings. International formats for floating point numbers and date/time values are also supported.

ChartText This class draws a string in the current chart window. It is the base class for the **ChartTitle**, **AxisTitle** and **ChartLabel** classes. The **ChartText** class also creates independent text objects. Other classes that display text also use it internally.

ChartTitle	This class displays a text string as the title or footer of the chart.
AxisTitle	This class displays a text string as the title for an axis. The axis title position is outside of the axis label area. Axis titles for y-axes are rotated 90 degrees.
ChartLabel	This class is the abstract base class of labels that require special formatting.
NumericLabel	This class is a concrete implementation of the **ChartLabel** class and it displays formatted numeric values.
TimeLabel	This class is a concrete implementation of the **ChartLabel** class and it displays formatted **ChartCalendar** dates.
ElapsedTimeLabel	This class is a concrete implementation of the **ChartLabel** class and it displays numeric values formatted as elapsed time strings **(12:32:21).**
StringLabel	This class is a concrete implementation of the **ChartLabel** class that formats string values for use as axis labels.

Miscellaneous Chart Classes

Marker
ChartImage
ChartShape
ChartSymbol

Various classes are used to position and draw objects that can be used as standalone objects in a graph, or as elements of other plot objects.

Marker	This class displays one of five marker types in a graph. The marker is used to create data cursors, or to mark data points.
ChartImage	This class encapsulates a **System.Drawing.Image** class, defining a rectangle in chart coordinates that the image is placed in. JPEG and other image files can be imported

using the **System.Drawing.Image** class and displayed in a chart.

ChartShape This class encapsulates a **System.Drawing.Drawing2D.GraphicsPath** class, placing the shape in a chart using a position defined in chart coordinates. A chart can display any object that can be defined using **System.Drawing.Drawing2D**.GraphicsPath class.

ChartSymbol This class defines symbols used by the **SimplePlot** scatter plot functions. Pre-defined symbols include square, triangle, diamond, cross, plus, star, line, horizontal bar, vertical bar, 3D bar and circle.

Mouse Interaction Classes

MouseListener
- **MoveObj**
- **FindObj**
- **DataToolTip**
- **DataCursor**
  - **MoveData**
- **MagniView**
- **MoveCoordinates**
- **ChartZoom**

Several classes implement delegates for mouse events. The **MouseListener** class implements a generic interface for managing mouse events in a graph window. The **DataCursor**, **MoveData**, **MoveObj, ChartZoom, MagniView and MoveCoordinates** classes also implement mouse event delegates that use the mouse to mark, move and zoom chart objects and data.

MouseListener This class implements .Net delegates that trap generic mouse events (button events and mouse motion events) that take place in a **ChartView** window. A programmer can derive a class from **MouseListener** and override the methods for mouse events, creating a custom version of the class.

MoveObj This class extends the **MouseListener** class and it can select chart objects and move them. Moveable chart objects include axes, axes labels, titles, legends, arbitrary text,

shapes and images. Use the **MoveData** class to move objects derived from **SimplePlot**.

FindObj This class extends the **MouseListener** class, providing additional methods that selectively determine what graphical objects intersect the mouse cursor.

DataCursor This class combines the **MouseListener** class and **Marker** class. Press a mouse button and the selected data cursor (horizontal and/or vertical line, cross hairs, or a small box) appears at the point of the mouse cursor. The data cursor tracks the mouse motion as long as the mouse button is pressed. Release the button and the data cursor disappears. This makes it easier to line up the mouse position with the tick marks of an axis.

MoveData This class selects and moves individual data points of an object derived from the **SimplePlot** class.

DataToolTip A data tooltip is a popup box that displays the value of a data point in a chart. The data value can consist of the x-value, the y-value, x- and y-values, group values and open-high-low-close values, for a given point in a chart.

ChartZoom This class implements mouse controlled zooming for one or more simultaneous axes. The user starts zooming by holding down a mouse button with the mouse cursor in the plot area of a graph. The mouse is dragged and then released. The rectangle established by mouse start and stop points defines the new, zoomed, scale of the associated axes. Zooming has many different modes. Some of the combinations are:

- One x or one y axis
- One x and one y axes
- One x and multiple y axes
- One y and multiple x axes
- Multiple x and y axes

MagniView This class implements mouse controlled magnification for one or more simultaneous axes. This class implements a chart magnify class based on the **MouseListener** class. It uses two charts; the source chart and the target chart. The source chart displays the chart in its unmagnified state. The target chart displays the chart in the magnified state. The mouse positions a **MagniView** rectangle within the source chart, and the target chart is re-scaled and redrawn to

match the extents of the **MagniView** rectangle from the source chart.

MoveCoordinates This class extends the **MouseListener** class and it can move the coordinate system of the underlying chart, analogous to moving (chaging the coordinates of) an internet map by "grabbing" it with the mouse and dragging it.

File and Printer Rendering Classes

ChartPrint
BufferedImage

ChartPrint This class implements printing using the .Net **System.Drawing.Printing** print-related services. It can select, setup, and output a chart to a printer.

BufferedImage This class will convert a **ChartView** object to a .Net **Image** object. Optionally, the class saves the buffered image to an image file.

Miscellaneous Utility Classes

ChartCalendar
CSV
Dimension
Point2D
GroupPoint2D
DoubleArray
DoubleArray2D
BoolArray
Point3D
NearestPointData
TickMark
Polysurface
Rectangle2D

ChartCalendar This class contains utility routines used to process **ChartCalendar** date objects.

CSV	This is a utility class for reading and writing CSV (Comma Separated Values) files.
Dimension	This is a utility class for handling dimension (height and width) information using doubles, rather than the integers used by the Size class.
Point2D	This class encapsulates an xy pair of values as doubles (more useful in this software than the .Net Point and PointF classes.
GroupPoint2D	This class encapsulates an x-value, and an array of y-values, representing the x and y values of one column of a group data set.
DoubleArray	This class is used as an alternative to the standard .Net Array class, adding routines for resizing of the array, and the insertion and deletion of double based data elements.
DoubleArray2D	This class is used as an alternative to the standard .Net 2D Array class, adding routines for resizing of the array, and the insertion and deletion of double based data elements.
BoolArray	This class is used as an alternative to the standard .Net Array class, adding routines for resizing of the array, and the insertion and deletion of bool based data elements.
Point3D	This class encapsulates an xyz set of double values used to specify 3D data values.
NearestPointData	This is a utility class for returning data that results from nearest point calculations.
TickMark	The axis classes use this class to to organize the location of the individual tick marks of an axis.
Polysurface	This is a utility class that defines complex 3D shapes as a list of simple 3-sided polygons. The contour plotting routines use it.
Rectangle2D	This is a utility class that extends the RectangleF class, using doubles as internal storage.

A diagram depicts the class hierarchy of the QCChart2D for .*Net* library.

ChartObj
- Arrow
- ChartCalendar
- CSV
- Dimension
- Point3D
- NearestPointData
- Polysurface
- ChartScale
  - LinearScale
  - LogScale
  - TimeScale
- UserCoordinates
  - WorldCoordinates
    - WorkingCoordinates
      - PhysicalCoordinates
        - CartesianCoordinates
          - PolarCoordinates
          - AntennaCoordinates
        - TimeCoordinates
- ChartDataset
  - SimpleDataset
    - TimeSimpleDataset
    - ElapsedTimeSimpleDataset
    - ContourDataset
  - GroupDataset
    - TimeGroupDataset
    - ElapsedTimeGroupDataset
- AutoScale
  - LinearAutoScale
  - LogAutoScale
  - TimeAutoScale
  - ElapsedTimeAutoScale
- MouseListener
  - MoveObj
  - FindObj
  - DataToolTip
  - ChartZoom
  - MagniView
  - MoveCoordinates

DataCursor
- MoveData

ChartAttribute
ChartGradient
ChartPrint
BufferedImage

System.Windows.Forms.UserControl
ChartView

Rectangle2D
Point2D
Point3D
GroupPoint2D
DoubleArray
DoubleArray2D
BoolArray
Polysurface

GraphObj
- AntennaAnnotation
- TickMark
- Axis
  - LinearAxis
    - PolarAxes
    - AntennaAxes
  - LogAxis
  - TimeAxis
- ChartText
  - ChartTitle
  - AxisTitle
  - ChartLabel
    - NumericLabel
      - BarDatapointValue
    - TimeLabel
    - ElapsedTimeLabel
    - StringLabel
  - AxisLabels
    - NumericAxisLabels
    - TimeAxisLabels
    - ElapsedTimeAxisLabels
    - StringAxisLabels
    - PolarAxesLabels
    - AntennaAxesLabels
- Grid
  - PolarGrid
  - AntennaGrid
- LegendItem
- BubblePlotLegendItem
- Legend
  - StandardLegend
  - BubblePlotLegend
- ChartPlot
  - SimplePlot
    - SimpleLinePlot
    - SimpleBarPlot
    - SimpleScatterPlot
    - SimpleLineMarkerPlot
    - SimpleVersaPlot
  - GroupPlot
    - ArrowPlot
    - BubblePlot
    - CandlestickPlot
    - CellPlot
    - ErrorBarPlot
    - FloatingBarPlot
    - FloatingStackedBarPlot
    - GroupBarPlot
    - HistogramPlot
    - LineGapPlot
    - MultiLinePlot
    - OHLCPlot
    - StackedBarPlot
    - StackedLinePlot
    - BoxWhiskerPlot
    - GroupVersaPlot
  - PieChart
  - PolarPlot
    - PolarLinePlot
    - PolarScatterPlot
  - AntennaPlot
    - AntennaLinePlot
    - AntennaScatterPlot
    - AntennaLineMarkerPlot
- Background
- ChartImage
- ChartShape
- ChartSymbol

Marker ChartZoom

5. SPC Control Data and Alarm Classes

SPCControlChartData
SPCControlLimitAlarmArgs
SPCControlLimitRecord
SPCCalculatedValueRecrod
SPCSampledValueRecord
SPCGeneralizedTableDisplay

The *Variable* and *Attribute Control Chart* classes share common data and alarm classes. SPC control chart data is stored in the **SPCControlChartData** class. It holds the header information used to customize the chart table, the raw sample data used to prepare the chart, the calculated chart values used in the chart, and the SPC control limits. It contains array lists of **SPCSampledValueRecord**, **SPCControlLimitRecord** and **SPCCalculatedValueRecord** objects. The **SPCGeneralizedTableDisplay** class manages **ChartText** objects used to display data in the table portion of the SPC chart.

Class SPCControlChartData

ChartObj
|
+-- SPCControlChartData

The **SPCControlChartData** class is the core data storage object for all of SPC Control Chart classes. It holds all of the data plotted in the SPC chart. That includes the header information used to customize the chart table,

Header Information

Title: Variable Control Chart (X-Bar & R)	Part No.: 283501	Chart No.: 17
Part Name: Transmission Casing Bolt	Operation: Threading	
Operator: J. Fenamore	Machine: #11	
Date: 11/28/2005 10:03:21 AM		

the raw sample data used in the SPC calculations,

Raw Sample Data

#1	23	25	23	23	27	25	30	24	35	27	36	29	35	26
#2	35	27	30	33	32	28	34	36	23	34	31	23	37	27
#3	24	26	30	34	35	27	26	32	28	36	25	25	24	25
#4	34	31	31	27	37	25	28	31	31	30	33	26	29	35
#5	31	28	35	23	31	25	34	28	36	32	25	29	35	33

the calculated chart values used in the chart, and the SPC control limits,

Calculated Values

MEAN	29.5	27.5	29.7	28.0	32.2	26.0	30.3	30.3	30.5	31.8	29.9	26.2	32.0	29.0
RANGE	12.4	6.2	11.8	11.1	9.9	3.1	8.5	11.5	12.8	9.7	11.2	6.4	13.5	9.8
SUM	147.7	137.4	148.5	140.2	161.2	130.1	151.3	151.6	152.7	159.1	149.5	130.8	159.8	145.1

and any notes you might want to place in the record.

Notes

NOTES	N	N	N	N	N	N	N	N	N	N	N	N	N	N

It contains array lists of **SPCSampledValueRecord**, **SPCControlLimitRecord** and **SPCCalculatedValueRecord** objects.

There is an instance of **SPCControlChartData** in the **SPCChartBase** class. Since the **SPCChartBase** class is the base class for the four major SPC Control Charts (**SPCBatchAttributeConrolChart**, **SPCBatchVariableControlChart**, **SPCTimeAttributeConrolChart**, **SPCTimeVariableControlChart**), it is accessible from those classes. The data elements of the **SPCControlChartData** class are accessible to the programmer.

SPCControlChartData Methods

The **SPCControlChartData** object is automatically created when the parent **SPCChartBase** object is created. The programmer does not need to instantiate it.

Public Static (Shared) Fields

CUSTOM_ATTRIBUTE_CONTROL_CHART	Chart type constant: Custom SPC Attribute Control Chart (unused)
CUSTOM_VARIABLE_CONTROL_CHART	Chart type constant: Custom SPC Variable Control Chart (not used)
DATALOG_FILE_ALL	Datalog flag specifying that all available items should be logged to the file.
DATALOG_FILE_BATCH_NUMBER	Datalog flag specifying that the batch number should be logged to the file.
DATALOG_FILE_CALCULATED_VALUES	Datalog flag specifying that the

	calculated values should be logged to the file.
DATALOG_FILE_COLUMN_HEADS	Datalog flag specifying that the column heads should be logged to the file.
DATALOG_FILE_CONTROL_LIMIT_VALUES	Datalog flag specifying that the control limit values should be logged to the file.
DATALOG_FILE_NOTES	Datalog flag specifying that the notes should be logged to the file.
DATALOG_FILE_SAMPLED_VALUES	Datalog flag specifying that the sampled values should be logged to the file.
DATALOG_FILE_TIME_STAMP	Datalog flag specifying that the time stamp should be logged to the file.
DATALOG_USER_STRING	Datalog flag specifying that the file prefix row ist NOT to be included. Using this option will make the file incompatible with the SPCControlChartData routines that read data files.
FRACTION_DEFECTIVE_PARTS_CHART	Chart type constant: Fraction Defective Parts (p-chart) Control Chart
HEADER_STRINGS_LEVEL0	SPC Chart header level constant: display no header strings.
HEADER_STRINGS_LEVEL1	SPC Chart header level constant: display minimal header strings, title, partNumber, chartNumber, dateString
HEADER_STRINGS_LEVEL2	SPC Chart header level constant: display most header strings, title, partNumber, chartNumber, partName, operation, operator, machine, dateString
HEADER_STRINGS_LEVEL3	SPC Chart header level constant: display all header strings, title, partNumber, chartNumber, partName, operation, operator, machine, specification limits, gage, unitofMeasure, zeroEqulas and dateString
INDIVIDUAL_RANGE_CHART	Chart type constant: Individual Range (Individual X) SPC Variable Control Chart

MEAN_RANGE_CHART	Chart type constant: Mean and Range (X-Bar R) SPC Variable Control Chart (
MEAN_SIGMA_CHART	Chart type constant: Mean and Sigma (X-Bar Sigma) SPC Variable Control Chart
MEAN_SIGMA_CHART_VSS	Chart type constant: Mean and Sigma (X-Bar Sigma) SPC Variable Control Chart with variable sample size
MEAN_VARIANCE_CHART	Chart type constant: Mean and Variance (X-Bar Variance) SPC Variable Control Chart
MEDIAN_RANGE_CHART	Chart type constant: Median and Range (Median-Range) SPC Variable Control Chart
NO_DATALOG_FILE_PREFIX	Datalog flag specifying that the file prefix row ist NOT to be included. Using this option will make the file incompatible with the SPCControlChartData routines that read data files.
NUMBER_DEFECTIVE_PARTS_CHART	Chart type constant: Number Defective Parts (np-chart) Control Chart
NUMBER_DEFECTS_CHART	Chart type constant: Number Defects (c-chart) Control Chart
NUMBER_DEFECTS_PERUNIT_CHART	Chart type constant: Number Defects per Unit (u-chart) Control Chart
PERCENT_DEFECTIVE_PARTS_CHART	Chart type constant: Percent Defective Parts (p-chart) Control Chart
SPC_PRIMARY_CONTROL_TARGET	Index of primary chart target control limit in controlLimitData array.
SPC_PRIMARY_LOWER_CONTROL_LIMIT	Index of primary chart lower control limit in controlLimitData array.
SPC_PRIMARY_UPPER_CONTROL_LIMIT	Index of primary chart upper control limit in controlLimitData array.
SPC_SECONDARY_CONTROL_TARGET	Index of secondary chart target control limit in controlLimitData array.
SPC_SECONDARY_LOWER_CONTROL_LIMIT	Index of secondary chart lower control limit in controlLimitData array.
SPC_SECONDARY_UPPER_CONTROL_LIMIT	Index of secondary chart upper

	control limit in controlLimitData array.

Public Static (Shared) Properties

BatchColumnHeadString	Default string used as the batch number column head in the log file. The default value is "Batch #"
DefaultAbsRangeString	Default string used to the y-axis of secondary chart of I-R charts.
DefaultDataLogFilenameRoot	Default string used as the default file name for data logging. Only used if data logging turned on and the DataLogFileOpenForWrite has not been initialized with an explicit filename. The current time is appended to the root to make it a unique filename.
DefaultHighAlarmMessageString	Default string used as the high alarm message for a low control limit.
DefaultLowAlarmMessageString	Default string used to the label the target lower control limit line of the chart.
DefaultLowControlLimitString	Default string used to the label the target low control limit line of the chart.
DefaultMeanString	Default string used to title the y-axis of mean graphs.
DefaultMedianString	Default string used to title the y-axis of median graphs.
DefaultRangeString	Default string used to title the y-axis of range graphs.
DefaultSampleValueString	Default string used to the y-axis of primary chart of I-R charts.
DefaultSigmaString	Default string used to title the y-axis of sigma graphs.
DefaultSumString	Default string used to title the sum table row.
DefaultTargetString	Default string used to the label the target control limit line of the chart.
DefaultUpperControlLimitString	Default string used to the label the target upper control limit line of the chart.
DefaultVarianceString	Default string used to title the y-axis of variance graphs.
DefaultXBarString	Default string used to title primary chart.
DefaultXString	Default string used to the primary chart of I-R charts.
NotesColumString	Default string used as the notes column head

	in the log file. The default value is "Notes"
SampleValueColumnString	Default string used as the sample value column head in the log file. The default value is "Sample #"
TimeStampColumnString	Default string used as the time stamp column head in the log file. The default value is "Time Stamp"

Public Static (Shared) Methods

CalcRangeBasedDecimalPos	Calculate the decimal precision used to display calculated values in the data table.

Public Instance Constructors

SPCControlChartData	Overloaded. Initializes a new instance of the SPCControlChartData class.

Public Instance Properties

AlarmStateEventEnable	Set to True to signify that any alarm should invoke the AlarmStateEventHandler.
AlarmTransitionEventEnable	Set to True to signify that any change in an alarm state should invoke the AlarmTransitionEventHandler.
ChartNumber	Set/Get data table chart number string.
ChartNumberHeader	Set/Get the header for the chartNumber field.
CurrentNumberRecords	Get the current number of records for the chart.
DatalLogEnable	Set to true to enable data logging. If a data log file has not been previously opened with DataLogFileOpenForWrite, a new data log file is created using the default name, combined with a time stamp.
DataLogCSV	The CSV (Comma Separated Value) specifyier for the logging data SPC data to a file.
DataLogFilename	The string used as the file name for data logging. Set when the DataLogFileOpenForWrite is called.
DataLogFlags	Set/Get the flags that control what items are logged to the data log file. The default has all of the optional items logged to the file. "OR" together individual data log file flags to specify the items you want logger to the file. For example: DatalogFlags = DATALOG_FILE_TIME_STAMP | DATALOG_FILE_SAMPLED_VALUES | DATALOG_FILE_CALCULATED_VALUES | DATALOG_FILE_COLUMN_HEADS. Use one of the SPCControlChartData datalog: DATALOG_FILE_BATCH_NUMBER,

	DATALOG_FILE_TIME_STAMP, DATALOG_FILE_SAMPLED_VALUES, DATALOG_FILE_CALCULATED_VALUES, DATALOG_FILE_CONTROL_LIMIT_VALUES , DATALOG_FILE_NOTES, DATALOG_FILE_COLUMN_HEADS.
DataLogUserString	The dataLogUserString is output as the second line in a datalog file, if the DATALOG_USER_STRING flag is set in dataLogFlags.
DateHeader	Set/Get the header for the dateString field.
DateString	Set/Get data table date string.
DefaultDefectRowHeaderPrefix	Set/Get the default symbol used for the row headers of the sample data items.
DefaultSampleRowHeaderPrefix	Set/Get the default symbol used for the row headers of the sample data items.
DefectiveDecimalPrecision	Set/Get the default value to use for the decimal precision used to display defective item counts, -1 = auto.
Gage	Set/Get data table gage string.
GageHeader	Set/Get the header for the gage field.
Machine	Set/Get data table machine string.
MachineHeader	Set/Get the header for the machine field.
NotesHeader	Set/Get the data table notes header string.
NotesMessage	Set/Get data table notes message string.
NotesToolTips	Set/Get the notes tool tip.
NumberSamplesValueRowHeader	Get/Set the data table number of samples row header.
NumCalculatedValues	Set/Get number of calculated values for each record in the chart.
NumRecordsPerChart	Set/Get the maximum number of records displayable at one time in the chart.
NumSampleCategories	Set/Get the number of categories in an Attribute Control chart. numSampleCategories == sampleSubgroupSize for Variable Control Charts
Operation	Set/Get data table operation string.
OperationHeader	Set/Get the header for the operation field.
OperatorHeader	Set/Get the header for the theOperator field.
PartName	Set/Get data table part name string.
PartNameHeader	Set/Get the header for the partName field.
PartNumber	Set/Get data table part number string.
PartNumberHeader	Set/Get the header for the partNumber field.
PrimaryCalculatedVariableIndex	Set/Get index in the calculatedValues array for the primary calculated value data.

SampleSubgroupSize	Set/Get the number of samples in a sample sub group for a Variable Control chart.
SecondaryCalculatedVariableIndex	Set/Get index in the calculatedValues array for the secondary calculated value data.
SPCChartType	Set/Get the control chart type: use one of the SPCControlChartData chart type constants: MEAN_RANGE_CHART, MEDIAN_RANGE_CHART, MEAN_SIGMA_CHART, MEAN_SIGMA_CHART_VSS, MEAN_VARIANCE_CHART, INDIVIDUAL_RANGE_CHART, EWMA_CHART, MA_CHART, MAMR_CHART, MAMS_CHART TABCUSUM_CHART, CUSTOM_ATTRIBUTE_CONTROL_CHART, PERCENT_DEFECTIVE_PARTS_CHART, FRACTION_DEFECTIVE_PARTS_CHART, NUMBER_DEFECTIVE_PARTS_CHART, NUMBER_DEFECTS_CHART, NUMBER_DEFECTS_PERUNIT_CHART, NUMBER_DEFECTS_PER_MILLION_CHART.
SpecificationLimits	Set/Get data table specification limits string.
SpecificationLimitsHeader	Set/Get the header for the specificationLimits field.
TheOperator	Set/Get data table operator string.
TimeStamp	Set/Get the time stamp for the most recent sample data added to the class.
TimeValueRowHeader	The data table time value row header.
Title	Set/Get data table title string.
TitleHeader	Set/Get the header for the title field.
UnitOfMeasure	Set/Get data table unit of measure string.
UnitOfMeasureHeader	Set/Get the header for the unit of measure field.
ZeroEquals	Set/Get data table zero equals string.
ZeroEqualsHeader	Set/Get the header for the zeroEqulas field.

Public Instance Methods

AddNewSampleRecord	Overloaded. Add a new sample record with notes to a time-based SPC chart that plots variable control limits.
AppendCurrentRecordValuesToDataLog	This methods will create a text file and append the current SPC data record to that file in a CSV (Comma Separated Value) format. A CSV file can be read by popular spreadsheet and word processing programs. Some localization for different operating

	systems and locales can be handled by the modifying the default csv (CSV) object.
Clone	Returns an object that is a clone of this object.
ControlLimitInitialized	Returns true if the control limit record at the index is initiated.
Copy	Overloaded. Copies the source object.
Copy (inherited from **ChartObj**)	Overloaded. Copies the source object.
DataLogFileOpenForWrite	Overloaded. This methods will create a text file and output the SPC chart data to that file in a CSV (Comma Separated Value) format. A CSV file can be read by popular spreadsheet and word processing programs. Some localization for different operating systems and locales can be handled by the modifying the default csv (CSV) object. Uses the dataLogFlags property as the guide to reading the values of the file, so that property must be properly initialized for the data file being read.
Equals (inherited from **Object**)	Determines whether the specified Object is equal to the current **Object**.
ErrorCheck (inherited from **ChartObj**)	Throws an exception if an error exists in the error chain.
ExcludeRecordFromControlLimitCalculations	Exclude the specified record from the SOC control limit calculations.
GetBatchNumberValue	Get the group number value at the specified index.
GetCalculatedValue	Get a calcualted value at a specific row (index) and column (time).
GetCalculatedValueRecord	Get the calculated value record at the specified index.
GetChartObjIDCntr (inherited from **ChartObj**)	Returns the current value of the chartObjIDCntr static counter.
GetChartObjType (inherited from **ChartObj**)	Returns the chart object type.
GetControlLimit	Get the value of a specific SPC chart limit.
GetControlLimitRecord	Get the control limit record at the specified index.
GetControlLimitString	Get the text for a specific SPC chart limit.
GetControlLimitText	Get the control limit text at the specified index.
GetControlLimitValue	Get a control limit value (for charts with variable control limits) at a specific row (index) and column (time).

GetHashCode (inherited from **Object**)	Serves as a hash function for a particular type, suitable for use in hashing algorithms and data structures like a hash table.
GetNotesString	Get the notes string at the specified index.
GetNumberOfSamplesPerSubgroup	Get the number of samples per subgroup value at the specified index.
GetPrimaryControlLimits	Overloaded. Using the current sampled data values, high, target and low control limits are calculated for the primary chart using an algorithm appropriate to the SPC chart type.
GetSampledValue	Get a sampled value at a specific row (index) and column (time).
GetSampleRowHeaderString	Get data table row header for the sampled (or category) item.
GetSecondaryControlLimits	Overloaded. Using the current sampled data values, high, target and low control limits are calculated for the primary chart using an algorithm appropriate to the SPC chart type.
GetThisChartObjID (inherited from **ChartObj**)	Returns the chartObjID value for this specific object.
GetTimeValue	Get the time stamp value at the specified index.
GetType (inherited from **Object**)	Gets the Type of the current instance.
GetYAxisTitle	Get the y-axis title or a specific index, based description of the item in the SPCCalculatedValueRecord or SPCSampledValueRecord record.
IsControlLimit	Returns true if the control limit record at the index is initiated.
OutputAllValuesToDataLog	Overloaded. This methods will create a text file and output all of the current SPC data records to that file in a CSV (Comma Separated Value) format. A CSV file can be read by popular spreadsheet and word processing programs. Some localization for different operating systems and locales can be handled by the modifying the default csv (CSV) object.
ReadAllValuesFromFile	Overloaded. This methods will read a text file of SPC data records organized in a CSV (Comma Separated Value) format. A CSV file can be read by popular spreadsheet and word processing programs. Some localization for different operating systems and locales can be handled by the

	modifying the default csv (CSV) object.
ResetSPCChartData	Reset the history buffers of all of the SPC data objects.
Save	Overloaded. This methods will create a text file and output the SPC chart data to that file in a CSV (Comma Separated Value) format. A CSV file can be read by popular spreadsheet and word processing programs. Some localization for different operating systems and locales can be handled by the modifying the default csv (CSV) object.
SetControlLimitString	Set the SPC text for a specific SPC chart limit.
SetControlLimitStrings	Set the SPC control limit text for an SPC control chart.
SetControlLimitValue	Set the SPC value of a specific SPC chart limit.
SetControlLimitValues	Set the SPC control limit values for an SPC control chart.
SetSampleRowHeaderString	Set data table row header for the sampled (or category) item.
SimulateDefectRecord	Overloaded. Simulates a defect measurement for a SPC Attribute Control chart with a specified mean. Used with NUMBER_DEFECTS_CHART and NUMBER_DEFECTS_PERUNIT_CHART charts.
SimulateMeasurementRecord	Overloaded. Simulates a sample measurement for a SPC Variable Control chart with a specified mean value.
SortAlarmObjectsByValue	This method sorts the objects in the controlLimitValues array in the ascending value of their alarm value.
ToString (inherited from **Object**)	Returns a String that represents the current Object.
TransitionEventCondition	Returns true if an alarm transition has taken place.

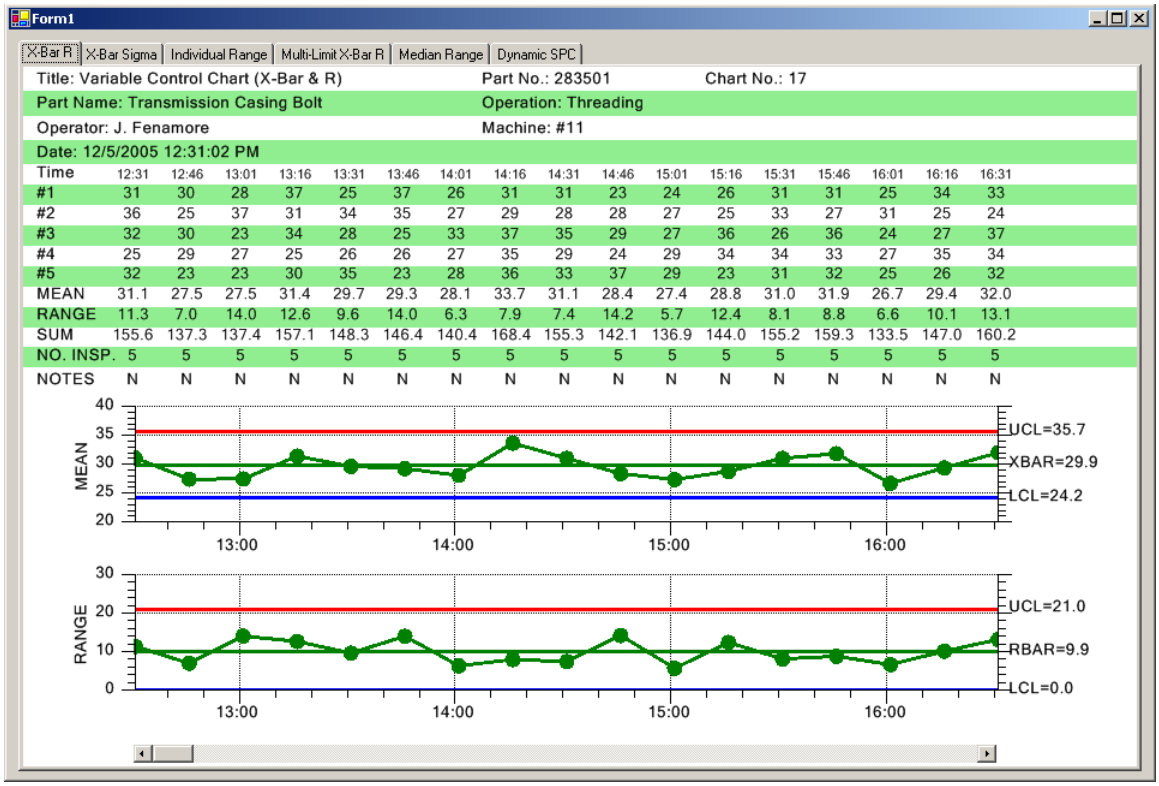
Public Instance Events

AlarmStateEventHandler	Delegate for nodification each time the check of an process variable produces an alarm state condition.
AlarmTransitionEventHandler	Delegate for notification each time the check of an process variable produces a change of state in alarm state condition.

Initializing the SPCControlChartData Class

The control charts **InitSPC**… method call initializes the **SPCControlChartData** object. This establishes the SPC chart type, how many samples per subgroup there are, and how many **SPCSampledValueRecord** objects are stored internal to the **SPCControlChartData** to handle the sampled data.

The table strings used to customize the first section of the chart should be set after the chart **InitSPC**… call, but before the **RebuildChartUsingCurrentData** call. The example below is from the **TimeVariableControlCharts.XBarRChart** example program.



[C#]

```
//  SPC variable control chart type
int charttype = SPCControlChartData.INDIVIDUAL_RANGE_CHART;
// Number of samples per sub group
int numsamplespersubgroup = 1;
// Number of data points  in the view
int numdatapointsinview = 17;
// The time increment between adjacent subgroups
int sampleincrement = 30;
```

```
public IndividualRangeChart()
{
    // This call is required by the Windows.Forms Form Designer.
    InitializeComponent();
    // Have the chart fill parent client area
    this.Dock = DockStyle.Fill;
    // Define and draw chart
    InitializeChart();
}

public  void InitializeChart()
{
//  if (this.IsDesignMode) return;
    // This call is required by the Windows.Forms Form Designer.
    InitializeComponent();
    // Initialize the SPCTimeVariableControlChart
    this.InitSPCTimeVariableControlChart(charttype,
        numsamplespersubgroup, numdatapointsinview, sampleincrement);

    // Set the strings used in the header section of the table
    this.ChartData.Title = "Variable Control Chart (X-Bar & R)";
    this.ChartData.PartNumber = "283501";
    this.ChartData.ChartNumber="17";
    this.ChartData.PartName= "Transmission Casing Bolt";
    this.ChartData.Operation = "Threading";
    this.ChartData.SpecificationLimits="";
    this.ChartData.TheOperator="J. Fenamore";
    this.ChartData.Machine="#11";
    this.ChartData.Gage="#8645";
    this.ChartData.UnitOfMeasure = "0.0001 inch";
    this.ChartData.ZeroEquals="zero";
    this.ChartData.DateString = DateTime.Now.ToString();
    this.ChartData.NotesMessage = "Control limits prepared May 10";
    this.ChartData.NotesHeader = "NOTES"; // row header
    this.HeaderStringsLevel = SPCControlChartData.HEADER_STRINGS_LEVEL1;
    .
    .
    .
    // Rebuild the chart using the current data and settings
    this.RebuildChartUsingCurrentData();

}
```

[VB]

```
'  SPC variable control chart type
Private charttype As Integer = SPCControlChartData.MEAN_RANGE_CHART
' Number of samples per sub group
Private numsamplespersubgroup As Integer = 5
' Number of data points  in the view
Private numdatapointsinview As Integer = 17
' The time increment between adjacent subgroups
Private timeincrementminutes As Integer = 15

#Region " Windows Form Designer generated code "

Public Sub New()
    .
    .
    .
  InitializeChart()
End Sub

#End Region


Public Sub InitializeChart()
    ' Initialize the SPCTimeVariableControlChart
```

```
    Me.InitSPCTimeVariableControlChart(charttype, _
           numsamplespersubgroup, numdatapointsinview, timeincrementminutes)


    ' Set the strings used in the header section of the table
    Me.ChartData.Title = "Variable Control Chart (Median Range)"
    Me.ChartData.PartNumber = "283501"
    Me.ChartData.ChartNumber = "17"
    Me.ChartData.PartName = "Transmission Casing Bolt"
    Me.ChartData.Operation = "Threading"
    Me.ChartData.SpecificationLimits = ""
    Me.ChartData.TheOperator = "J. Fenamore"
    Me.ChartData.Machine = "#11"
    Me.ChartData.Gage = "#8645"
    Me.ChartData.UnitOfMeasure = "0.0001 inch"
    Me.ChartData.ZeroEquals = "zero"
    Me.ChartData.DateString = DateTime.Now.ToString()
    Me.ChartData.NotesMessage = "Control limits prepared May 10"
    Me.ChartData.NotesHeader = "NOTES" ' row header
    Me.HeaderStringsLevel = SPCControlChartData.HEADER_STRINGS_LEVEL1
    .
    .
    .
    Me.RebuildChartUsingCurrentData()
End Sub 'InitializeChart
```

Update the sampled data with your measured values using one of the **AddNewSampleRecord** methods.

Method AddNewSampleRecord

This method adds a new sample record to the SPC chart. While *both variable control charts* and *attribute control charts* share the same **ChartData AddNewSampleRecord** methods, the meaning of the data in the *samples* array varies, depending on the chart type. See the sections below: *Adding New Sample Records for Variable Control Charts*, and *Adding New Sample Records for Attribute Control Charts*.

[VB]

```
Overloads Public Sub AddNewSampleRecord( _
   ByVal timestamp As ChartCalendar, _
   ByVal samples As DoubleArray, _
   ByVal notes As String _
)
```

[C#]

```
public void AddNewSampleRecord(
   ChartCalendar timestamp,
   DoubleArray samples,
   string notes
);
```

Parameters

timestamp

Time stamp for the current sample record.

samples

Array of new sample values.

notes

A string specifying any notes associated with this sample subgroup

controllimits

Array of control limits, one for each control limits (low, target, and high)

There are many other overloaded versions of **AddNewSampleRecord**. Use the one most appropriate to your application.

Adding New Sample Records for Variable Control Charts (Fixed Subgroup Sample Size).

Applies to variable control charts of type: MEAN_RANGE_CHART, MEDIAN_RANGE_CHART, INDIVIDUAL_RANGE_CHART, MEAN_SIGMA_CHART, INDIVIDUAL_RANGE_CHART, EWMA_CHART, MA_CHART, MAMR_CHART, MAMS_CHART, TABCUSUM_CHART.

In variable control charts, each data value in the *samples* array represents a specific sample in the sample subgroup. In X-Bar R, X-Bar Sigma, and Median-Range charts, where the sample subgroup size is some fraction of the total production level, there is one value in the *samples* array for each measurement sample in the sample subgroup interval. If the production level is sixty items per hour, and the sample size is five items per hour, then the graph would be updated once an hour with five items in the *samples* array.

[C#]

```
DoubleArray samples = new DoubleArray(5);
//  ChartCalendar initialized with current  time by default
ChartCalendar timestamp = new ChartCalendar();
// Place sample values in array
samples[0] = 0.121;     // First of five samples
samples[1] = 0.212;     // Second of five samples
samples[2] = 0.322;     // Third of five samples
samples[3] = 0.021;     // Fourth of five samples
samples[4] = 0.133;     // Fifth of five samples

// Add the new sample subgroup to the chart
this.ChartData.AddNewSampleRecord(timestamp, samples);
```

[VB]

```
Dim samples As DoubleArray = New DoubleArray(5)
'  ChartCalendar initialized with current  time by default
Dim timestamp As ChartCalendar = New ChartCalendar()
' Place sample values in array
samples(0) = 0.121    ' First of five samples
samples(1) = 0.212    ' Second of five samples
samples(2) = 0.322    ' Third of five samples
samples(3) = 0.021    ' Fourth of five samples
samples(4) = 0.133    ' Fifth of five samples

' Add the new sample subgroup to the chart
 Me.ChartData.AddNewSampleRecord(timestamp, samples)
```

In an Individual-Range chart, which by definition samples 100% of the production level, the *samples* array would only have one value for each update. If the production level is sixty items per hour, with 100% sampling, the graph would be updated once a minute, with a single value in the *samples* array.

Adding New Sample Records to a X-Bar Sigma Chart (Variable Subgroup Sample Size)

Applies to variable control charts of type: MEAN_SIGMA_CHART_VSS

The X-Bar Sigma chart also comes in a version where variable sample sizes are permitted, As in the standard variable control charts, there is one value in the *samples* array for each measurement sample in the sample subgroup interval. The difference is that the length of the *samples* array can change from update to update. It is critically import that the size of the samples array exactly matches the number of samples in the current subgroup

[C#]

```
// GetCurrentSampleSubgroupSize is a fictional method that gets the
// current number of samples in the  sample subgroup. The value of N
// can vary from sample interval to sample interval. You must have a
// valid sample value for each element.

N = GetCurrentSampleSubgroupSize();

// Size array exactly to a length of N
DoubleArray samples = new DoubleArray(N);
//  ChartCalendar initialized with current  time by default
ChartCalendar timestamp = new ChartCalendar();

// Place sample values in array
// You must have a valid sample value for each element of the array size 0..N-1
samples[0] = 0.121;     // First of five samples
samples[1] = 0.212;     // Second of five samples
.
.
.
samples[N-1] = 0.133;       // Last of the samples in the sample subgroup

// Add the new sample subgroup to the chart
this.ChartData.AddNewSampleRecord(timestamp, samples);
```

[VB]

```
' GetCurrentSampleSubgroupSize is a fictional method that gets the
' current number of samples in the  sample subgroup. The value of N
' can vary from sample interval to sample interval. You must have a
' valid sample value for each element.

N = GetCurrentSampleSubgroupSize()

' Size array exactly to a length of N
Dim samples As DoubleArray = New DoubleArray(N)
'  ChartCalendar initialized with current  time by default
Dim timestamp As ChartCalendar = New ChartCalendar()
' Place sample values in array
samples(0) = 0.121     ' First of five samples
samples(1) = 0.212     ' Second of five samples
```

```
.
.
.
samples(N-1) = 0.133    ' Last of the samples in the sample subgroup

' Add the new sample subgroup to the chart
 Me.ChartData.AddNewSampleRecord(timestamp, samples)
```

Adding New Sample Records for Attribute Control

Updating p- and np-charts (Fixed Sample Subgroup Size)

p-chart = FRACTION_DEFECTIVE_PARTS_CHART
or
PERCENT_DEFECTIVE_PARTS_CHART

np-chart = NUMBER_DEFECTIVE_PARTS_CHART

In attribute control charts, the meaning of the data in the *samples* array varies, depending on whether the attribute control chart measures the number of defective parts (p-, and np-charts), or the total number of defects (u- and c-charts). The major anomaly is that while the p- and np-charts plot the fraction or number of defective parts, the table portion of the chart can display defect counts for any number of defect categories (i.e. paint scratches, dents, burrs, etc.). It is critical to understand that total number of defects, i.e. the sum of the items in the defect categories for a give sample subgroup, do NOT have to add up to the number of defective parts for the sample subgroup. Every defective part not only can have one or more defects, it can have multiple defects of the same defect category. The total number of defects for a sample subgroup will always be equal to or greater than the number of defective parts. When using p- and np-charts that display defect category counts as part of the table, where N is the *numcategories* parameter in the **InitSPCTimeAttributeControlChart** or **InitSPCBatchAttributeControlChart** initialization call, the first N (0.. N-1) elements of the *samples* array holds the defect count for each category. The (N+1)th (or element N in the array) element of the *samples* array holds the total defective parts count. For example, if you initialized the chart with a *numcategories* parameter to five, signifying that you had five defect categories, you would use a *samples* array sized to six, as in the code below:

[C#]

```
DoubleArray samples = new DoubleArray(6);
//  ChartCalendar initialized with current  time by default
ChartCalendar timestamp = new ChartCalendar();
// Place sample values in array
samples[0] = 3;     // Number of defects for defect category #1
samples[1] = 0;     // Number of defects for defect category #2
samples[2] = 4;     // Number of defects for defect category #3
samples[3] = 2;     // Number of defects for defect category #4
samples[4] = 3;     // Number of defects for defect category #5

samples[5] = 4;    // TOTAL number of defective parts in the sample
```

```
// Add the new sample subgroup to the chart
this.ChartData.AddNewSampleRecord(timestamp, samples);
```

[VB]

```
Dim samples As DoubleArray = New DoubleArray(6)
'  ChartCalendar initialized with current  time by default
Dim timestamp As ChartCalendar = New ChartCalendar()
' Place sample values in array
samples(0) = 3      ' Number of defects for defect category #1
samples(1) = 0      ' Number of defects for defect category #2
samples(2) = 4      ' Number of defects for defect category #3
samples(3) = 2      ' Number of defects for defect category #4
samples(4) = 3      ' Number of defects for defect category #5

samples(5) = 4     ' TOTAL number of defective parts in the sample

' Add the new sample subgroup to the chart
 Me.ChartData.AddNewSampleRecord(timestamp, samples)
```

Our example programs obscure this a bit, because we use a special method to simulate defect data for n- and np-charts. The code below is extracted from our TimeAttributeControlCharts.NumberDefectivePartsControlChart example program.

[C#]

```
DoubleArray samples = this.ChartData.SimulateDefectRecord(50 * 0.134,
       SPCControlChartData.NUMBER_DEFECTIVE_PARTS_CHART);
// Add new sample record
this.ChartData.AddNewSampleRecord( timestamp, samples);
```

[VB]

```
Dim samples As DoubleArray = Me.ChartData.SimulateDefectRecord(50 * 0.134, _
    SPCControlChartData.NUMBER_DEFECTIVE_PARTS_CHART)
' Add new sample record
Me.ChartData.AddNewSampleRecord(timestamp, samples)
```

This particular overload for **ChartData.SimulateDefectRecord** knows that since it is a NUMBER_DEFECTIVE_PARTS_CHART chart (np-chart), and since the **ChartData** object was setup with five categories in the **InitSPCTimeAttributeControlChart** call, that is should return a **DoubleArray** with (5 + 1 = 6) elements. The first five elements representing simulated defect counts for the five defect categories, and the sixth element the simulated defective parts count. The defect category count data of the *samples* array is only used in the table part of the display; the defect category counts play NO role in the actual SPC chart. The only value plotted in the SPC chart is the last element in the *samples* array, the defective parts count for the sample subgroup.

Updating p-charts (Variable Sample Subgroup Size)

p-chart = FRACTION_DEFECTIVE_PARTS_CHART_VSS

or

PERCENT_DEFECTIVE_PARTS_CHART_VSS

First, you must read the previous section (**Updating p-charts (Fixed Sample Subgroup Size**) and understand it**.** Because in the case of the p-chart variable sample subgroup case, filling out that array is EXACTLY the same as the fixed sample subgroup case. The number of defects in each defect category go into the first N elements (element 0..N-1) of the samples array. The total number of defective parts go into last (element N) of the samples array. Specify the size of the sample subgroup associated with a given update using the **ChartData.SampleSubgroupSize_VSS** property.

[C#]

```
DoubleArray samples = this.ChartData.SimulateDefectRecord(50 * 0.134,
       SPCControlChartData.NUMBER_DEFECTIVE_PARTS_CHART);

// Randomize the sample subgroup size to some value less than the maximum
// value entered in the call to InitSPCTimeAttributeControlChart,
// and set the charts ChartData.SampleSubgroupSize_VSS property with
//  this value immediately prior to the AddNewSampleRecord call.
this.ChartData.SampleSubgroupSize_VSS =
    numsamplespersubgroup - (int)(25 * ChartSupport.GetRandomDouble());

// Add new sample record
this.ChartData.AddNewSampleRecord( timestamp, samples);
```

[VB]

```
Dim samples As DoubleArray = Me.ChartData.SimulateDefectRecord(50 * 0.134, _
    SPCControlChartData.NUMBER_DEFECTIVE_PARTS_CHART)

' Randomize the sample subgroup size to some value less than the maximum
' value entered in the call to InitSPCTimeAttributeControlChart,
' and set the charts ChartData.SampleSubgroupSize_VSS property with
'  this value immediately prior to the AddNewSampleRecord call.
Me.ChartData.SampleSubgroupSize_VSS = _
    numsamplespersubgroup - (25 * ChartSupport.GetRandomDouble())


' Add new sample record
Me.ChartData.AddNewSampleRecord(timestamp, samples)
```

Updating c- and u-charts (Fixed Sample Subgroup Size)

c-chart = NUMBER_DEFECTS_CHART

u-chart = NUMBER_DEFECTS_PERUNIT_CHART

In c- and u-charts the number of defective parts is of no consequence. The only thing tracked is the number of defects. Therefore, there is no extra array element tacked onto the end of the *samples* array. Each element of the *samples* array represents the total number of defects for a given defect category. If the *numcategories* parameter in the **InitSPCTimeAttributeControlChart** or **InitSPCBatchAttributeControlChart** is

initialized to five, the total number of elements in the *samples* array should be five. For example:

[C#]

```
DoubleArray samples = new DoubleArray(5);
//  ChartCalendar initialized with current  time by default
ChartCalendar timestamp = new ChartCalendar();
// Place sample values in array
samples[0] = 3;     // Number of defects for defect category #1
samples[1] = 0;     // Number of defects for defect category #2
samples[2] = 4;     // Number of defects for defect category #3
samples[3] = 2;     // Number of defects for defect category #4
samples[4] = 3;     // Number of defects for defect category #5

// Add the new sample subgroup to the chart
this.ChartData.AddNewSampleRecord(timestamp, samples);
```

[VB]

```
Dim samples As DoubleArray = New DoubleArray(5)
'  ChartCalendar initialized with current  time by default
Dim timestamp As ChartCalendar = New ChartCalendar()
' Place sample values in array
samples(0) = 3      ' Number of defects for defect category #1
samples(1) = 0      ' Number of defects for defect category #2
samples(2) = 4      ' Number of defects for defect category #3
samples(3) = 2      ' Number of defects for defect category #4
samples(4) = 3      ' Number of defects for defect category #5

' Add the new sample subgroup to the chart
 Me.ChartData.AddNewSampleRecord(timestamp, samples)
```

Updating u-charts (Variable Sample Subgroup Size)

u-chart = NUMBER_DEFECTS_PERUNIT_CHART_VSS

First, you must read the previous section (**Updating u-charts Fixed Sample Subgroup Size**) and understand it**.** Because in the case of the u-chart variable sample subgroup case, filling out that array is EXACTLY the same as the fixed sample subgroup case. The number of defects in each defect category go into the first N elements (element 0..N-1) of the samples array. Specify the size of the sample subgroup associated with a given update using the **ChartData.SampleSubgroupSize_VSS** property.

[C#]

```
DoubleArray samples = new DoubleArray(5);
//  ChartCalendar initialized with current  time by default
ChartCalendar timestamp = new ChartCalendar();
// Place sample values in array
samples[0] = 3;     // Number of defects for defect category #1
samples[1] = 0;     // Number of defects for defect category #2
samples[2] = 4;     // Number of defects for defect category #3
samples[3] = 2;     // Number of defects for defect category #4
samples[4] = 3;     // Number of defects for defect category #5

// Randomize the sample subgroup size to some value less than the maximum
```

```
// value entered in the call to InitSPCTimeAttributeControlChart,
// and set the charts ChartData.SampleSubgroupSize_VSS property with
//  this value immediately prior to the AddNewSampleRecord call.
this.ChartData.SampleSubgroupSize_VSS =
    numsamplespersubgroup - (int)(25 * ChartSupport.GetRandomDouble());

// Add the new sample subgroup to the chart
this.ChartData.AddNewSampleRecord(timestamp, samples);
```

[VB]

```
Dim samples As DoubleArray = New DoubleArray(5)
'  ChartCalendar initialized with current  time by default
Dim timestamp As ChartCalendar = New ChartCalendar()
' Place sample values in array
samples(0) = 3      ' Number of defects for defect category #1
samples(1) = 0      ' Number of defects for defect category #2
samples(2) = 4      ' Number of defects for defect category #3
samples(3) = 2      ' Number of defects for defect category #4
samples(4) = 3      ' Number of defects for defect category #5

' Randomize the sample subgroup size to some value less than the maximum
' value entered in the call to InitSPCTimeAttributeControlChart,
' and set the charts ChartData.SampleSubgroupSize_VSS property with
'  this value immediately prior to the AddNewSampleRecord call.
Me.ChartData.SampleSubgroupSize_VSS = _
    numsamplespersubgroup - (25 * ChartSupport.GetRandomDouble())

' Add the new sample subgroup to the chart
 Me.ChartData.AddNewSampleRecord(timestamp, samples)
```

While the table portion of the display can display defect data broken down into categories, only the sum of the defects for a given sample subgroup is used in creating the actual SPC chart. Note that the code below, extracted from the TimeAttributeControlCharts.NumberDefectsControlChart example, uses a different **ChartData.SimulateDefectRecord** method to simulate the defect data.

[C#]

```
// Simulate sample record
DoubleArray samples = this.ChartData.SimulateDefectRecord(19.85/5);
// Add a sample record
this.ChartData.AddNewSampleRecord( timestamp, samples);
```

[VB]

```
' Simulate sample record
  Dim samples As DoubleArray = Me.ChartData.SimulateDefectRecord((19.85 / 5))
   ' Add a sample record
 Me.ChartData.AddNewSampleRecord(timestamp, samples)
```

Other AddNewSampleRecord Methods

Add a new sample record to a time-based SPC chart.

public void AddNewSampleRecord(ChartCalendar,DoubleArray);

Add a new sample record with notes to a time-based SPC chart.

public void AddNewSampleRecord(ChartCalendar,DoubleArray,string);

Add a new sample record to a batch-based SPC chart.

public void AddNewSampleRecord(DoubleArray);

Add a new sample record, with notes, to a batch-based SPC chart.

public void AddNewSampleRecord(DoubleArray,string);

Add a new sample record to a numeric-based SPC chart.

public void AddNewSampleRecord(double,ChartCalendar,DoubleArray,DoubleArray,string);

Add a new sample record, with notes, to a numeric-based SPC chart .

public void AddNewSampleRecord(double,ChartCalendar,DoubleArray,string);

Add a new sample record, with notes, to a batch-based SPC chart.

public void AddNewSampleRecord(double,DoubleArray);

Add a new sample record, with notes, to a batch-based SPC chart.

public void AddNewSampleRecord(double,DoubleArray,string);
In addition to these, there are versions that pass in an additional **DoubleArray** that pass in the current value of variable control limits, if used. See the QCSPCChartNetCompiledHelpFile.chm compiled help file, under com.quinncurtis.spcchartnet | **SPCControlChartData.AddNewSampleRecord.**

If the **AddNewSampleRecord** overload does not have an explicit **ChartCalendar** time stamp parameter, as in the case several of the overloaded methods, the current time as stored in the system clock is used as the time stamp.

Question - How do you initialize the ChartCalendar object with your own time. Answer - Just use one of the many ChartCalendar constructors. See the QCChart2DNetCompiledHelpFile.chm compiled help file.

> This constructor creates a new **ChartCalendar** object using the specified **DateTime** value.
>
> public ChartCalendar(DateTime);
>
> This constructor creates a new **ChartCalendar** object using the specified year, month and day.
>
> public ChartCalendar(int,int,int);

This constructor creates a new **ChartCalendar** object using the specified year, month, day, hour, minute and second.

public ChartCalendar(int,int,int,int,int,int);

This constructor creates a new **ChartCalendar** object using the specified year, month, day, hour, minute, second and milliseconds.

public ChartCalendar(int,int,int,int,int,int,int);

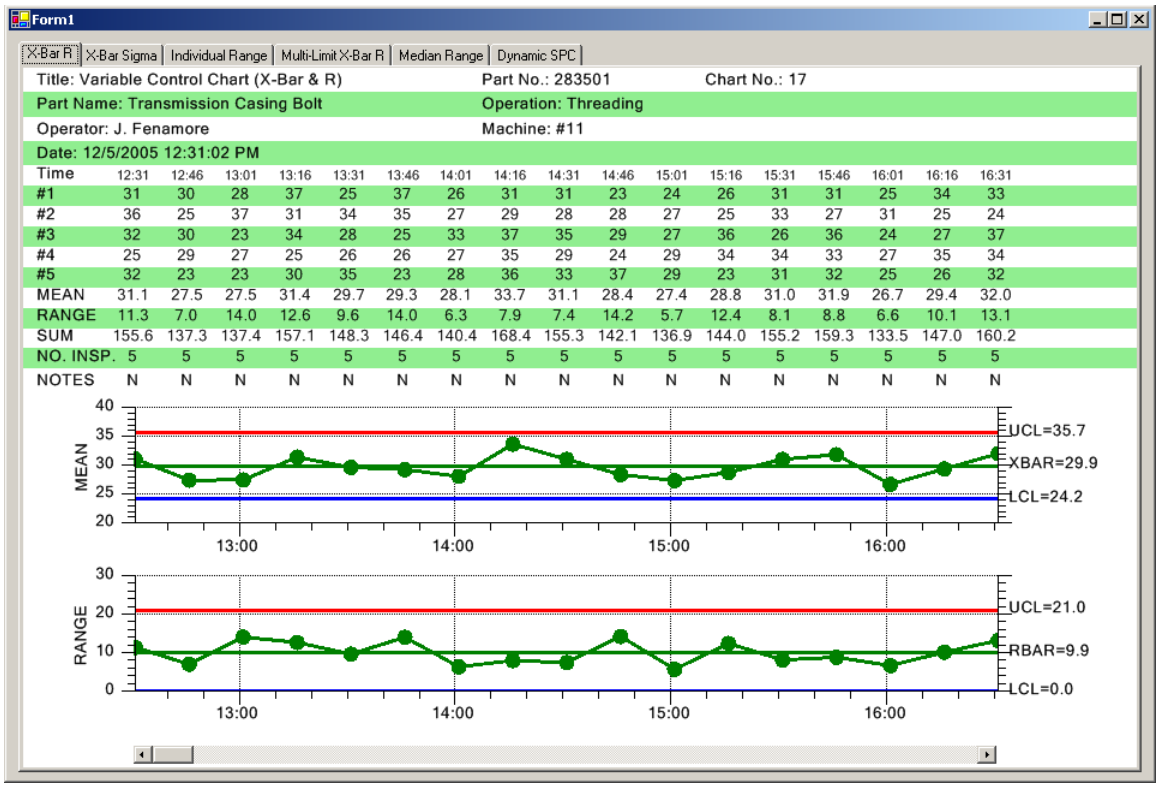
This constructor creates a new **ChartCalendar** object using the designated number of ticks.

public ChartCalendar(long);

This constructor creates a new **ChartCalendar** object using the designated number of milliseconds, or seconds.

public ChartCalendar(long,bool);

The sampled values initialize the chart after the **InitSPC**… call, but before the **RebuildChartUsingCurrentData** call. The example below is from the **TimeVariableControlCharts.XBarRChart** example program. The **AddNewSampleRecord** routine is called in the **SimulateData** method.



[C#]

```
public void InitializeChart()
{
    this.InitSPCTimeVariableControlChart(charttype, numcategories,
        numsamplespersubgroup, numdatapointsinview, timeincrementminutes);

    .
    .
    .
    SimulateData();

    this.AutoCalculateControlLimits();
    this.AutoScalePrimaryChartYRange();
    this.AutoScaleSecondaryChartYRange();
    this.RebuildChartUsingCurrentData();

}

private void SimulateData()
{  String notesstring = "";
    for (int i=0; i < 200; i++)
    {
        ChartCalendar timestamp = (ChartCalendar) startTime.Clone();
        // Use the ChartData sample simulator to make an array of sample data
        DoubleArray samples = this.ChartData.SimulateMeasurementRecord(30, 10);
        .
        .
        .
        // Add the new sample subgroup to the chart
        this.ChartData.AddNewSampleRecord(timestamp, samples, notesstring);
        // increment simulated time by timeincrementminutes minutes
        startTime.Add(ChartObj.MINUTE, timeincrementminutes);
    }
}
```

[VB]

```
Public Sub InitializeChart()
 ' Initialize the SPCTimeVariableControlChart
     Me.InitSPCTimeVariableControlChart(charttype, numsamplespersubgroup, _
        numdatapointsinview, timeincrementminutes)
    .
    .
    .
    ' Must have data loaded before any of the Auto.. methods are called
    SimulateData()

    ' Calculate the SPC control limits for both graphs of the current SPC chart
    Me.AutoCalculateControlLimits()
    ' Scale the y-axis of the X-Bar chart to display all data and control limits
    Me.AutoScalePrimaryChartYRange()
    ' Scale the y-axis of the Range chart to display all data and control limits
    Me.AutoScaleSecondaryChartYRange()
    ' Rebuild the chart using the current data and settings
    Me.RebuildChartUsingCurrentData()
End Sub 'InitializeChart


Private Sub SimulateData()
    Dim notesstring As [String] = ""
    Dim i As Integer
    For i = 0 To 199
        Dim timestamp As ChartCalendar = CType(startTime.Clone(), ChartCalendar)
        ' Use the ChartData sample simulator to make an array of sample data
        Dim samples As DoubleArray =
           Me.ChartData.SimulateMeasurementRecord(30, 10)
       .
       .
       .
       Me.ChartData.AddNewSampleRecord(timestamp, samples, notesstring)
       ' increment simulated time by timeincrementminutes minutes
       startTime.Add(ChartObj.MINUTE, timeincrementminutes)
    Next i
End Sub 'SimulateData
```

Logging SPC Data to a File

The **SPCControlChartData** method contains routines that log SPC data to a file in a CSV (comma separated value) format. The first row of the file is a prefix of data that defines options and the number of columns associated with sample data, calculated data and control limit data. The second row of data are the column heads for each item in the data log. Starting with the third row, SPC data is output, record by record. If the data logging feature is turned on, every call to the **AddNewSampleRecord** method will result in the output of that record, and calculated values, to the data log.

A typical datalog file (both the width and length of the data file are truncated) appears below.

```
File prefix:    62,5,3,6
Column Heads:   Time Stamp,Sample #0,Sample #1,Sample #2,…
Record #1:      1/24/2006 12:03:40,22.946081345643,30.6379105980219,…
Record #2:      1/24/2006 12:18:40,23.8902424375481,33.7523682840412,…
Record #3:      1/24/2006 12:33:40,33.1602680593078,28.2172109399537,…
```

The values in the file prefix have the following meaning

63 Data log options = SPCControlChartData.DATALOG_FILE_TIME_STAMP |

SPCControlChartData.DATALOG_FILE_SAMPLED_VALUES |

SPCControlChartData.DATALOG_FILE_CALCULATED_VALUES |

SPCControlChartData.DATALOG_FILE_COLUMN_HEADS |

SPCControlChartData.DATALOG_FILE_NOTES

5 There are five sampled values per record

3 There are three calculated values per record (MEAN, RANGE, SUM for example)

6 There are six control limit values per record (`XBAR,LCL,UCL,RBAR,LCL,UCL) for example`

If you want to view a complete datalog file, run the TimeVariableControlCharts example program and after you terminate the program, view the Datalogfile1.text file in the [C#] TimeVariableControlCharts\Bin\Debug folder, or [VB] TimeVariableControlCharts\Bin folder. The following steps, extracted from the TimeVariableControlChart.VariableControlLimitsCharts example program, turn on data logging:

[C#]

```
int datalogflags = SPCControlChartData.DATALOG_FILE_TIME_STAMP |
    SPCControlChartData.DATALOG_FILE_SAMPLED_VALUES |
    SPCControlChartData.DATALOG_FILE_CALCULATED_VALUES |
    SPCControlChartData.DATALOG_FILE_COLUMN_HEADS |
    SPCControlChartData.DATALOG_FILE_NOTES;

    this.ChartData.DataLogFileOpenForWrite("DatalogFile1.txt", datalogflags);
    this.ChartData.DatalLogEnable = true;
.
.
.
    this.ChartData.AddNewSampleRecord(timestamp, samples, notesstring);
```

[VB]

```
Dim datalogflags As Integer = SPCControlChartData.DATALOG_FILE_TIME_STAMP Or _
    SPCControlChartData.DATALOG_FILE_SAMPLED_VALUES Or _
    SPCControlChartData.DATALOG_FILE_CALCULATED_VALUES Or _
    SPCControlChartData.DATALOG_FILE_COLUMN_HEADS Or _
    SPCControlChartData.DATALOG_FILE_NOTES

    Me.ChartData.DataLogFileOpenForWrite("DatalogFile1.txt", datalogflags)
    Me.ChartData.DatalLogEnable = True
.
.
.
```

```
Me.ChartData.AddNewSampleRecord(timestamp, samples, notesstring)
```

Every call to the **AddNewSampleRecord** method will append a new SPC record to the file specified in the **DataLogFileOpenForWrite** call.

Specify what items are logged to the datalog file using the **DataLogFlag** property. OR the datalog flags constants together to form the final **DataLogFlags** value.

DATALOG_FILE_ALL	Datalog flag specifying that all available items should be logged to the file.
DATALOG_FILE_BATCH_NUMBER	Datalog flag specifying that the batch number should be logged to the file.
DATALOG_FILE_CALCULATED_VALUES	Datalog flag specifying that the calculated values should be logged to the file.
DATALOG_FILE_COLUMN_HEADS	Datalog flag specifying that the column heads should be logged to the file.
DATALOG_FILE_CONTROL_LIMIT_VALUES	Datalog flag specifying that the control limit values should be logged to the file.
DATALOG_FILE_NOTES	Datalog flag specifying that the notes should be logged to the file.
DATALOG_FILE_SAMPLED_VALUES	Datalog flag specifying that the sampled values should be logged to the file.
DATALOG_FILE_TIME_STAMP	Datalog flag specifying that the time stamp should be logged to the file.

[C#]

```
this.ChartData.DataLogFlags = SPCControlChartData.DATALOG_FILE_TIME_STAMP |
    SPCControlChartData.DATALOG_FILE_SAMPLED_VALUES |
    SPCControlChartData.DATALOG_FILE_CALCULATED_VALUES |
    SPCControlChartData.DATALOG_FILE_COLUMN_HEADS |
    SPCControlChartData.DATALOG_FILE_NOTES;
```

[VB]

```
Me.ChartData.DataLogFlags = SPCControlChartData.DATALOG_FILE_TIME_STAMP Or _
    SPCControlChartData.DATALOG_FILE_SAMPLED_VALUES Or _
    SPCControlChartData.DATALOG_FILE_CALCULATED_VALUES Or _
    SPCControlChartData.DATALOG_FILE_COLUMN_HEADS Or _
```

```
    SPCControlChartData.DATALOG_FILE_NOTES
```

It is also possible to read a previously saved datalog file and initialize the **ChartData** object with previously collected data. While the data can be initialized, it is still important that the originating **SPCChartBase** object is initialized properly for the data it is to receive. Use the **ChartData.ReadAllValuesFromFile** method to read previously saved values. The example below is extracted from the TimeVariableControlChart.VariableControlLimitsCharts example program.

[VB]

```
Me.InitSPCTimeVariableControlChart(charttype, numsamplespersubgroup, _
        numdatapointsinview, timeincrementminutes)

.
.
.
If (File.Exists("DatalogFile1.txt")) Then
   Me.ChartData.ReadAllValuesFromFile("DatalogFile1.txt")
```

[C#]

```
this.InitSPCTimeVariableControlChart(charttype,
        numsamplespersubgroup, numdatapointsinview, timeincrementminutes);
.
.
.
if (File.Exists("DatalogFile1.txt"))
{
    this.ChartData.ReadAllValuesFromFile("DatalogFile1.txt");
}
```

It is important that the *charttype* parameter matches the chart type used to save the original data, and that the *numberofsamplepersubgroup* value matches the number of samples in the original data.

Control Limit Alarms

Class SPCControlLimitRecord

ChartObj
        |
        +-- SPCControlLimitRecord

The **SPCControlLimitRecord** stores control limit alarm information for the **SPCControlChartData** class. The **SPCControlLimitRecord** class specifies the type of the alarm, the alarm limit value, alarm text messages and alarm hysteresis value. The **SPCControlChartData** classes store the **SPCControlLimitRecord** objects in the **SPCControlChartData**.**ControlLimitValues** array list

SPCControlLimitRecord constructors

This constructor creates a new instance of a **SPCControlLimitRecord** object, using the specified spc data object, calculated value object, alarm type, alarm limit value and alarm message.

[VB]
```
Overloads Public Sub New( _
   ByVal processvar As SPCControlChartData, _
   ByVal clr As SPCCalculatedValueRecord, _
   ByVal parametertype As Integer, _
   ByVal alarmlimitvalue As Double, _
   ByVal normalmessage As String, _
   ByVal alarmmessage As String _
)
```

[C#]
```
public SPCControlLimitRecord(
   SPCControlChartData processvar,
   SPCCalculatedValueRecord clr,
   int parametertype,
   double alarmlimitvalue,
   string normalmessage,
   string alarmmessage
);
```

Parameters

processvar
: Specifies the process variable that the alarm is attached to.

clr
: Specifies the calculated value record the alarm is attached to.

parametertype
: Specifies the alarm type: SPC_NOTA_LIMIT, SPC_LOWERTHAN_LIMIT, or SPC_GREATERTHAN_LIMIT.

alarmlimitvalue
: Specifies the alarm limit value.

normalmessage
: Specifies display message when no alarm present.

alarmmessage
: Specifies the alarm message.

The most commonly used **SPCControlLimitRecord** properties are:

Public Static (Shared) Fields

SPC_GREATERTHAN_LIMIT	Specifies the alarm is a greater than alarm.
SPC_LOWERTHAN_LIMIT	Specifies the alarm is a lower than alarm.
SPC_NOTA_LIMIT	Specifies the limit is not an alarm, just a

value.

Public Instance Constructors

SPCControlLimitRecord	Overloaded. Initializes a new instance of the **SPCControlLimitRecord** class.

Public Instance Properties

AlarmDisplay	Get/Set the alarm display flag.
AlarmEnable	Get/Set the alarm enable flag.
AlarmMessage	Get/Set the current alarm message.
AlarmState	Get/Set the alarm state, true if the last call to CheckAlarm show that the process variable currently in alarm.
CalculatedValueSrc	Set/Get a reference to the SPCCalculatedValueRecord object associated with the control limit.
ControlLimitText	Get/Set the Normal alarm message;
ControlLimitType	Get/Set the alarm type: SPC_NOTA_LIMIT, SPC_LOWERTHAN_LIMIT, or SPC_GREATERTHAN_LIMIT.
ControlLimitValue	Get/Set the alarm limit value.
ControlLimitValues	Get/Set the controlLimitValues array.
HysteresisValue	Get/Set the alarm hysteresis value.
PrevAlarmState	Get/Set the previous alarm state.
SPCProcessVar	Get/Set the spcDataVar object.
SymbolColor	Get/Set the alarm symbol color.
TextColor	Get/Set the alarm text color.

Public Instance Methods

CheckAlarm	Overloaded. Check the current value against the parameterValue.
Clone	Returns an object that is a Clone of this **SPCControlLimitRecord** object.
Copy	Overloaded. Copies the source **SPCControlLimitRecord** object.
ErrorCheck	Checks the **SPCControlLimitRecord** object for common errors. Current error state. Returns an error code.
GetAlarm	Returns the current alarm state based on the passed in value.
GetControlLimitHistoryValue	Get a values for the controlLimitsValues historical buffer.
SetControlLimitValue	Set current value of the control limit and

adds that value to the controlLimitValues historical array.

The **SPCControlLimitRecord** properties are documented in the QCSPCChartNetCompiledHelpFile.chm documentation file, located in the \doc subdirectory.

Example of trapping SPCControlLimitRecord alarm using an event delegate

The example below specifies an alarm event delegate for the control limit alarms. The example was extracted from the **TimeVariableControlCharts.DynamicXBarRChart** example program.

[C#]

```
public void InitializeChart()
{

    // TODO: Add any initialization after the InitForm call

    // Initialize the SPCTimeVariableControlChart
    this.InitSPCTimeVariableControlChart(charttype,
        numsamplespersubgroup, numdatapointsinview, timeincrementminutes);
    // Set the strings used in the header section of the table
    this.ChartData.Title = "Variable Control Chart (X-Bar & R)";
    .
    .
    .

    this.ChartData.AlarmStateEventHandler +=
        new SPCControlLimitAlarmEventDelegate(this.SPCControlLimitAlarm);
    // don't generate alarms in initial data simulation
    this.ChartData.AlarmStateEventEnable = false;

    SimulateData();
    .
    .
    .
    //  generate alarms starting now
    this.ChartData.AlarmStateEventEnable = true;
}

private void SPCControlLimitAlarm(object sender, SPCControlLimitAlarmArgs e)
    {
        SPCControlLimitRecord alarm = e.EventAlarm;
        double alarmlimitvalue = alarm.ControlLimitValue;
        String alarmlimitvaluestring = alarmlimitvalue.ToString();

        SPCControlChartData spcData = alarm.SPCProcessVar;
        SPCCalculatedValueRecord spcSource = e.SPCSource;
        String calculatedvaluestring = spcSource.CalculatedValue.ToString();

        String message = alarm.AlarmMessage;
        ChartCalendar timestamp = spcData.TimeStamp;
        String timestampstring = timestamp.ToString();

        if (alarm.AlarmState)
            Console.Out.WriteLine(timestampstring + " " + message + "=" +
                    alarmlimitvaluestring + " Current Value" + "=" +
                    calculatedvaluestring);
```

```
    }
}
```

[VB]

```
Public Sub InitializeChart()
    .
    .
    .
    ' Initialize the SPCTimeVariableControlChart
    Me.InitSPCTimeVariableControlChart(charttype, numsamplespersubgroup, _
        numdatapointsinview, timeincrementminutes)
    .
    .
    .
    AddHandler Me.ChartData.AlarmStateEventHandler, _
           AddressOf Me.SPCControlLimitAlarm
   ' don't generate alarms in initial data simulation
    Me.ChartData.AlarmStateEventEnable = False

    SimulateData()
    .
    .
    .

    Me.RebuildChartUsingCurrentData()

End Sub 'InitializeChart


Private Sub SPCControlLimitAlarm(ByVal sender As Object, _
    ByVal e As SPCControlLimitAlarmArgs)
   Dim alarm As SPCControlLimitRecord = e.EventAlarm
   Dim alarmlimitvalue As Double = alarm.ControlLimitValue
   Dim alarmlimitvaluestring As [String] = alarmlimitvalue.ToString()
   Dim spcData As SPCControlChartData = alarm.SPCProcessVar
   Dim spcSource As SPCCalculatedValueRecord = e.SPCSource
   Dim calculatedvaluestring As [String] = spcSource.CalculatedValue.ToString()
   Dim message As [String] = alarm.AlarmMessage
   Dim timestamp As ChartCalendar = spcData.TimeStamp
   Dim timestampstring As [String] = timestamp.ToString()
   If alarm.AlarmState Then
        Console.Out.WriteLine((timestampstring + " " + message + "=" +
        alarmlimitvaluestring + " Current Value" + "=" +
        calculatedvaluestring))
   End If
End Sub 'SPCControlLimitAlarm
```

Control Limit Alarm Event Handling

Class SPCControlLimitAlarmArgs

ChartObj

|

+-- SPCControlLimitAlarmArgs

The **SPCControlChartData** class can throw an alarm event based on either the current alarm state, or an alarm transition from one alarm state to another. The

SPCControlLimitAlarmArgs passes alarm data to the event handler. If you want the alarm event triggered only on the initial transition from the no-alarm state to the alarm state, set the **SPCControlChartData.AlarmTransitionEventEnable** to true and the **SPCControlChartData.AlarmStateEventEnable** to false**.** In this case, you will get one event when the process variable goes into alarm, and one when it comes out of alarm. If you want a continuous stream of alarm events, as long as the **SPCControlLimitRecord** object is in alarm, set the **SPCControlChartData.AlarmTransitionEventEnable** to false and the **SPCControlChartData.AlarmStateEventEnable** to true. The alarm events will be generated at the same rate as the **SPCControlChartData.AddNewSampleRecord()** method is called.

SPCControlLimitAlarmArgs constructors

You don't really need the constructors since **SPCControlLimitAlarmArgs** objects are created inside the **SPCControlChartData** class when an alarm event needs to be generated.

The most commonly used **SPCControlLimitAlarmArgs** properties are:

Selected Public Instance Properties

Public Instance Properties

AlarmChannel	Get/Set the alarm channel associated with the alarm.
EventAlarm	Get/Set the **SPCControlLimitRecord** object.
SPCSource	Get/Set the SPCCalculatedValueRecord object associated with the alarm.

A complete listing of **SPCControlLimitAlarmArgs** properties are documented in the QCSPCChartNetCompiledHelpFile.chm documentation file, located in the \doc subdirectory.

Example

Setup and enable an alarm transition event handler in the following manner:
[C#]

```
this.ChartData.AlarmTransitionEventHandler+=
    new SPCControlLimitAlarmEventDelegate(this.SPCControlLimitAlarm);
this.ChartData.AlarmTransitionEventEnable = true;
```

[VB]

```
AddHandler Me.ChartData.AlarmTransitionEventHandler, _
       AddressOf Me.SPCControlLimitAlarm
Me.ChartData.AlarmTransitionEventEnable = true
```

where the handler method is **this.SPCControlLimitAlarm**

[C#]

```
private void SPCControlLimitAlarm(object sender, SPCControlLimitAlarmArgs e)
{
    .
    .
    .
}
```

[VB]

```
Private Sub SPCControlLimitAlarm(ByVal sender As Object, _
    ByVal e As SPCControlLimitAlarmArgs)
.
.
.
.
End Sub 'SPCControlLimitAlarm
```

Setup and enable an alarm state event handler in an identical manner:
[C#]

```
this.ChartData.AlarmStateEventHandler +=
    new SPCControlLimitAlarmEventDelegate(this.SPCControlLimitAlarm);
this.ChartData.AlarmStateEventEnable = true;
```

[VB]

```
 AddHandler Me.ChartData.AlarmStateEventHandler, _
           AddressOf Me.SPCControlLimitAlarm
  Me.ChartData.AlarmStateEventEnable = True
```

where the handler method is this **SPCControlLimitAlarm**.

[C#]

```
private void SPCControlLimitAlarm(object sender, SPCControlLimitAlarmArgs e)
{
    .
    .
    .
}
```

[VB]

```
Private Sub SPCControlLimitAlarm(ByVal sender As Object, _
    ByVal e As SPCControlLimitAlarmArgs)
.
.
.
.
End Sub 'SPCControlLimitAlarm
```

SPCSampledValueRecord

This class encapsulates a sample data value. It includes a description for the item, the current value of the sampled value, and a history of previous values.

An array list of **SPCSampledValueRecord** objects, one for each sample category, is automatically created when the parent **SPCChartBase** object is created. The programmer does not need to instantiate it.

Public Instance Constructors

SPCSampledValueRecord	Overloaded. Initializes a new instance of the SPCSampledValueRecord class.

Public Instance Properties

SampledValue	Get/Set the current value for this record.
SampledValues	Get/Set the historical array of the sampled value record.
ValueDescription	Get/Set the description of sampled value record.

Public Instance Methods

Copy	Copies the source object.
GetCalculatedValueStatistic	Calculate a statistic for the historical data associated with the sample item.
SetSampledValue	Set the current value of the record, and adds the value to the historical array of the sampled value record.

SPCControlLimitRecord

This class holds information specific to a SPC control limit: including the current value of the control limit, a history of control limit values, description, and the hysteresis value for alarm checking.

Public Static (Shared) Fields

SPC_GREATERTHAN_LIMIT	Specifies the alarm is a greater than alarm.
SPC_LOWERTHAN_LIMIT	Specifies the alarm is a lower than alarm.
SPC_NOTA_LIMIT	Specifies the limit is not an alarm, just a value.

Public Instance Constructors

SPCControlLimitRecord	Overloaded. Initializes a new instance of the **SPCControlLimitRecord** class.

Public Instance Fields

controlLimitValues	A historical record of the control limit values.

Public Instance Properties

AlarmDisplay	Get/Set the alarm display flag.
AlarmEnable	Get/Set the alarm enable flag.
AlarmMessage	Get/Set the current alarm message.
AlarmState	Get/Set the alarm state, true if the last call to CheckAlarm show that the process variable currently in alarm.
ControlLimitText	Get/Set the Normal alarm message;
ControlLimitType	Get/Set the alarm type: SPC_NOTA_LIMIT, SPC_LOWERTHAN_LIMIT, or SPC_GREATERTHAN_LIMIT.
ControlLimitValue	Get/Set the alarm limit value.
ControlLimitValues	Get/Set the controlLimitValues array.
HysteresisValue	Get/Set the alarm hysteresis value.
PrevAlarmState	Get/Set the previous alarm state.
SPCProcessVar	Get/Set the spcDataVar object.
SymbolColor	Get/Set the alarm symbol color.
TextColor	Get/Set the alarm text color.

Public Instance Methods

CheckAlarm	Check the current value against the parameterValue.
Clone	Returns an object that is a Clone of this **SPCControlLimitRecord** object.
Copy	Overloaded. Copies the source **SPCControlLimitRecord** object.
Copy (inherited from **ChartObj**)	Overloaded. Copies the source object.
ErrorCheck	Checks the **SPCControlLimitRecord** object for common errors. Current error state. Returns an error code.
GetAlarm	Returns the current alarm state based on the passed in value.
GetControlLimitHistoryValue	Get a values for the controlLimitsValues historical buffer.
SetControlLimitValue	Set current value of the control limit and adds that value to the controlLimitValues historical array.

SPCCalculatedValueRecord

This is the record class for a calculated SPC statistic. It holds the calculated value type (mean, median, sum, variance, standard deviation, etc.), value, description and historical data.

Public Static (Shared) Fields

SPC_CUSTOM_CALC	Constant value for a custom SPC calculation (unused).
SPC_FRACTION_DEFECTIVE_PARTS_CALC	Constant value for a percent defective parts SPC calculation.
SPC_FRACTION_DEFECTS_CALC	Constant value for a fraction defects SPC calculation.
SPC_INDIVIDUAL_ABS_RANGE_CALC	Constant value for a ABS individual range SPC calculation.
SPC_INDIVIDUAL_COPY_VALUE	Constant value for INDIVIDUAL RANGE .
SPC_INDIVIDUAL_RANGE_CALC	Constant value for a individual range SPC calculation.
SPC_MAX_CALC	Constant value for a maximum SPC calculation.
SPC_MEAN_CALC	Constant value for a mean SPC calculation.
SPC_MEAN_N_MINUS_1_CALC	Constant value for a mean SPC calculation using N-1, rather than N.
SPC_MEDIAN_CALC	Constant value for a median SPC calculation.
SPC_MIN_CALC	Constant value for a minimum SPC calculation.
SPC_PERCENT_DEFECTIVE_PARTS_CALC	Constant value for a percent defective parts calculation.
SPC_PERCENT_DEFECTS_CALC	Constant value for a percent defects SPC calculation.
SPC_RANGE_CALC	Constant value for a range SPC calculation.
SPC_STD_DEVIATION_CALC	Constant value for a standar deviation SPC calculation.
SPC_SUM_CALC	Constant value for a sum SPC calculation.
SPC_TOTAL_DEFECTIVE_PARTS_CALC	Constant value for a total defective parts SPC calculation.
SPC_TOTAL_DEFECTS_CALC	Constant value for a total defects SPC

	calculation.
SPC_VARIANCE_CALC	Constant value for a variance SPC calculation.

Public Static (Shared) Methods

CalculateHistoryStatistic	Calculate the calculated value value based on the data in the source array and the specified calculation type.

Public Instance Constructors

SPCCalculatedValueRecord	Overloaded. Initializes a new instance of the SPCCalculatedValueRecord class.

Public Instance Properties

CalculatedValue	Get the current calculation value for this record.
CalculatedValues	Get the reference to the calculatedValue array.
CalculationType	Set/Get the calculation type for this calculation value record. Use one of the SPCCalculatedValueRecord calculation type constants.
MostRecentSampledValues	Get/Set an array holding the values of the most recent sampled, or measured values used in calculating the records calculateValue value.
ValidValueFlags	Get the reference to the validValueFlags array.
ValueDescription	Get/Set the description of calculation value record.

Public Instance Methods

Copy	Copies the source object.
GetCalculatedValueStatistic	Returns the calculated value value based on the data in the calculated historical data array, calculatedValues. Excludes values that are marked invalid in the validValueFlags array.
IsValueValid	Checks to the validValueFlags to see if a value in the calculated historical data array, calculatedValues, is valid.
SetCalculatedValue	Overloaded. Calculate the calculated value value based on the data in the source array. Sets the calculatedValue property of the class to the result.

SPCProcessCapabilityRecord

This is the record class for calculating and storing SPC process capability statistics. It supports calculating the Cp, Cpl, Cpu, Cpk, Cpm, Pp, Ppl, Ppu, and Ppk statistics.

Public Static (Shared) Fields

SPC_CP_CALC	Constant value CP calculation.
SPC_CPK_CALC	Constant value CPK calculation.
SPC_CPL_CALC	Constant value CPL calculation.
SPC_CPM_CALC	Constant value CPM calculation.
SPC_CPU_CALC	Constant value CPU calculation.
SPC_CUSTOM_PC_CALC	Constant value for a custom SPC calculation (unused).
SPC_PP_CALC	Constant value for a sum SPC calculation.
SPC_PPK_CALC	Constant value PPK calculation.
SPC_PPL_CALC	Constant value PPL calculation.
SPC_PPU_CALC	Constant value PPU calculation.

Public Static (Shared) Properties

DefaultProcessCapabilityStrings	Default descriptors for the process capability strings: "", "Cp", "Cpl", "Cpu","Cpk","Pp", "Pl","Pu","Ppk".

Public Instance Constructors

SPCProcessCapabilityRecord	Overloaded. Initializes a new instance of the SPCProcessCapabilityRecord class.

Public Instance Properties

CalculationType	Set/Get the calculation type for this calculation value record. Use one of the SPCProcessCapabilityRecord calculation type constants.
CurrentValue	Get the current calculation value for this record.
CurrentValues	Get the reference to the currentValue array.
LSLValue	Get the LSL value for this record.
USLValue	Get the USL value for this record.
ValidValueFlags	Get the reference to the validValueFlags array.
ValueDescription	Get/Set the description of calculation value record.

Public Instance Methods

CalculateProcessCapabilityValue	Calculate the process capability value..
CalculateProcessCapabilityValues	Calculate the process capability value..
Clone	Returns an object that is a clone of this object.
Copy	Overloaded. Copies the source object.
IsValueValid	Checks to the validValueFlags to see if a value in the calculated historical data array, currentValues, is valid.
Reset	Reset the history buffer of the SPCProcessCapabilityRecord class.
SetProcessCapabilityValue	Calculate the process capability value. Sets the currentValue property of the class to the result.

SPCGeneralizedTableDisplay

This class manages a list of **ChartText** objects (**NumericLabel**, **StringLabel** and **TimeLabel** objects), that encapsulate each unique table entry in the SPC chart table. This class also manages the spacing between the rows and columns of the table, and the alternating stripe used as a background for the table.

Public Static (Shared) Fields

NUMERIC_ROW_SPACING	Constant specifies that the next row to the table should user numeric row spacing.
TABLE_NO_COLOR_BACKGROUND	Constant specifies that the table does not use a background color.
TABLE_SINGLE_COLOR_BACKGROUND	Constant specifies that the table uses a single color for the background (backgroundColor1).
TABLE_SINGLE_COLOR_BACKGROUND_GRID	Constant specifies that the table uses horizontal stripes of color for the background (backgroundColor1 and backgroundColor2).
TABLE_STRIPED_COLOR_BACKGROUND	Constant specifies that the table uses horizontal stripes of color for the background (backgroundColor1 and backgroundColor2).
TEXT_ROW_SPACING	Constant specifies that the next row to the table should user text

row spacing.

Public Static (Shared) Properties

DefaultTableFont	Set/Get the default font used in the table display.

Public Instance Constructors

SPCGeneralizedTableDisplay	Overloaded. Initializes a new instance of the SPCGeneralizedTableDisplay class.

Public Instance Properties

BackgroundBarXOffset	Set/Get the background bar left offset, in normalized coordinates.
BackgroundColor1	Set/Get the first of two colors used in the alternating background colors used to delineate the table rows.
BackgroundColor2	Set/Get the second of two colors used in the alternating background colors used to delineate the table rows.
CalculatedItemTemplate	Get/Set the CalculatedItemTemplate object used as a template for displaying calculated numeric values in the table.
CalculatedLabelFont	Get/Set the font used in the display of calculated numeric values in the table.
CurrentColumnPosition	Get/Set the current column position.
CurrentRowPosition	Get/Set the current column position.
NotesItemTemplate	Get/Set the StringItemTemplate object used as a template for displaying string values in the table.
NotesLabelFont	Get/Set the font used in the display of string values in the table.
NumericColumnSpacing	Get/Set the numeric column spacing.
NumericRowSpacing	Get/Set the numeric row spacing.
SampleItemTemplate	Get/Set the SampleItemTemplate object used as a template for displaying numeric values in the table.
SampleLabelFont	Get/Set the font used in the display of sample numeric values in the table.
StartColumnPosition	Get/Set the starting x-position, in normalized coordinates, of the left-most column of the table.
StartRowPosition	Get/Set the starting y-position, in normalized coordinates, of the first row of the table.

StringItemTemplate	Get/Set the StringItemTemplate object used as a template for displaying string values in the table.
StringLabelFont	Get/Set the font used in the display of string values in the table.
TableBackgroundMode	Set/Get the first of two colors used in the alternating background colors used to delineate the table rows.
TextColumnSpacing	Get/Set the text column spacing.
TextRowOffset	Set/Get the offset between the start of the row and the top of the text, in normalized coordinates.
TextRowSpacing	Get/Set the text row spacing.
TimeColumnSpacing	Get/Set the time column spacing.
TimeItemTemplate	Get/Set the TimeLabel object used as a template for displaying time values in the table.
TimeLabelFont	Get/Set the font used in the display of time values in the table.
TimeRowSpacing	Get/Set the time row spacing.

Public Instance Methods

AddCalculatedItem	Overloaded. Add a calculated numeric item to the table, using the specified column spacing increment.
AddHorizontalBar	Add a horizontal bar as a row background for the table.
AddNotesItem	Overloaded. Add a string item to the table, using the specified column spacing increment.
AddNumericItem	Overloaded. Add a numeric item to the table, using the specified column spacing increment.
AddStringItem	Overloaded. Add a string item to the table, using the specified column spacing increment.
AddTimeItem	Overloaded. Add a time item to the table, using the specified column spacing increment.
Clone	Returns an object that is a clone of this object.
Copy	Overloaded. Copies the source object.
GetChartLabel	Get a specific ChartLabel object in the chartLabelArray array list.

IncrementRow	Overloaded. Add another row to the table, using the specified row spacing increment.
InitDefaults	Initialize default values for the class.

6. SPC Variable Control Charts

SPCTimeVariableControlChart
SPCBatchVariableControlChart

Variable Control Charts are used with sampled quality data that can be assigned a specific numeric value, other than just 0 or 1. This includes, but is not limited to, the measurement of a critical dimension (height, length, width, radius, etc.), the weight a specific component, or the measurement of an important voltage. The variable control charts supported by this software include X-Bar R (Mean and Range), X-Bar Sigma, Median and Range, X-R (Individual Range), MA (Move Average), MAMR (Moving Average / Moving Range), MAMS (Moving Average / Moving Sigma), EWMA (Exponentially Weighted Moving Average) and CUSum charts.

X-Bar R Chart – Also known as the Mean (or Average) and Range Chart

The X-Bar R chart monitors the trend of a critical process variable over time using a statistical sampling method that results in a subgroup of values at each sample interval. The X-Bar part of the chart plots the mean of each sample subgroup and the Range part of the chart monitors the difference between the minimum and maximum value in the subgroup. X-Bar R charts are created using the **SPCTimeVariableControlChart** and **SPCBatchVariableControlChart** classes.

X-Bar Sigma – Also known as the X-Bar S Chart

Very similar to the X-Bar R chart, the X-Bar Sigma chart replaces the Range plot with a Sigma plot based on the standard deviation of the measured values within each subgroup. This is a more accurate way of establishing control limits if the sample size of the subgroup is moderately large (> 10). Though computationally more complicated, the use of a computer makes this a non-issue. The X-Bar Sigma chart comes in fixed sample subgroup size, and variable sample subgroup size, versions. . X-Bar Sigma charts are created using the **SPCTimeVariableControlChart** and **SPCBatchVariableControlChart** classes.

Median Range – Also known as the Median and Range Chart

Very similar to the X-Bar R Chart, Median Range chart replaces the Mean plot with a Median plot representing the median of the measured values within each subgroup. In order to use a Median Range chart the process needs to be well behaved, where the variation in measured variables are (1) known to be distributed normally, (2) are not very often disturbed by assignable causes, and (3) are easily adjusted. . Median Range charts are created using the **SPCTimeVariableControlChart** and **SPCBatchVariableControlChart** classes.

Individual Range Chart – Also known as the X-R Chart

The Individual Range Chart is used when the sample size for a subgroup is 1. This happens frequently when the inspection and collection of data for quality control purposes is automated and 100% of the units manufactured are analyzed. It also happens when the production rate is low and it is inconvenient to have sample sizes other than 1. The X part of the control chart plots the actual sampled value (not a mean or median) for each unit and the R part of the control chart plots a moving range that is calculated using the current value of sampled value minus the previous value. . Individual Range charts are created using the **SPCTimeVariableControlChart** and **SPCBatchVariableControlChart** classes.

EWMA Chart – Exponentially Weighted Moving Average

The EWMA chart is an alternative to the preceding Shewhart type control charts (X-Bar R and I-R charts in particular) and is most useful for detecting small shifts in the process mean. It uses a weighted moving average of previous values to "smooth" the incoming data, minimizing the affect of random noise on the process. It weights the current and most recent values more heavily than older values, allowing the control line to react faster than a simple MA (Moving Average) plot to changes in the process. Like the Shewhart charts, if the EWMA value exceeds the calculated control limits, the process is considered out of control. While it is usually used where the process uses 100% inspection and the sample subgroup size is 1 (same is the X-R chart), it can also be used when sample subgroup sizes are greater than one. EWMA charts are created using the **SPCTimeVariableControlChart** and **SPCBatchVariableControlChart** classes.

MA Chart – Moving Average

The MA chartis another alternative to the preceding Shewhart type control charts (X-Bar Rand I-R charts in particular) and is most useful for detecting small shifts in the process mean. It uses a moving average, where the previous (N-1) sample values of the process variable are averaged together along with the current value to produce the current chart value. This helps to "smooth" the incoming data, minimizing the affect of random noise on the process. Unlike the EWMA chart the MA chart weights the current and previous (N-1) values equally in the average. While the MA chart can often detect small changes in the process mean faster than the Shewhart chart types, it is generally less effective than either the EWMA chart, or the CuSum chart MA charts are created using the **SPCTimeVariableControlChart**and **SPCBatchVariableControlChart**classes.

MAMR Chart – Moving Average/Moving Range

The MAMR chart combines our Moving Average chart with a Moving Range chart. The Moving Average chart is primary (topmost) chart, and the Moving Range chart is the secondary (bottom) chart. It uses a single sample/subgroup, same as our standard [Individual-Range], [Moving Average], [EWMA], and [Moving Average] charts. When calculating the Moving Range, it windows the same data values used in the Moving Average calculation. Note that the limits are variable (wider) at the beginning, taking into account the fewer samples in the start up of any type of SPC chart which uses a sliding window in the calculation of moving average and moving range statistics.

MAMS Chart – Moving Average / Moving Sigma

The MAMS chart combines our Moving Average chart with a Moving Sigma chart. The Moving Average chart is primary (topmost) chart, and the Moving Sigma chart is the secondary (bottom) chart. It uses a single sample/subgroup, same as our standard [Individual-Range], [Moving Average], [EWMA], and [Moving Average] charts. When calculating the Moving Sigma, it windows the same data values used in the Moving Average calculation. Note that the limits are variable (wider) at the beginning, taking into account the fewer samples in the start up of any type of SPC chart which uses a sliding window in the calculation of moving average and moving sigma statistics.

CuSum Chart – Tabular, one-sided, upper and lower cumulative sum

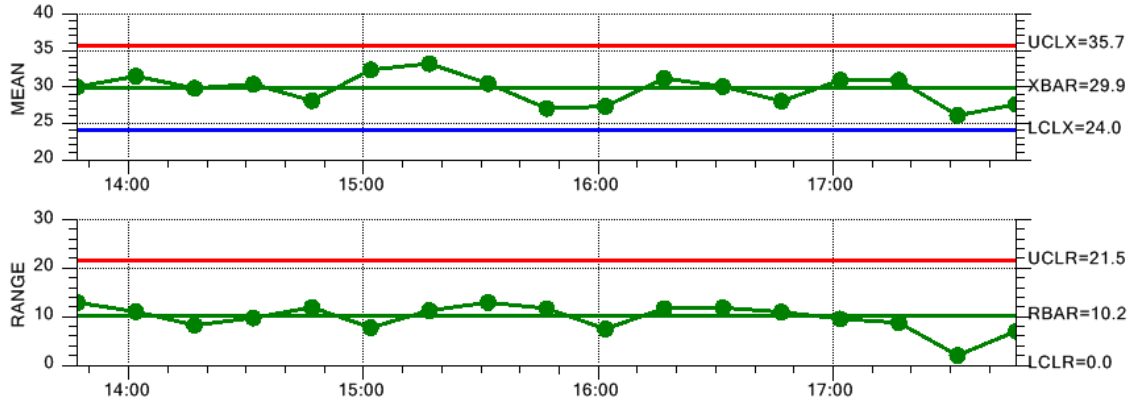
The CuSum chart is a specialized control chart, which like the EWMA and MA charts, is considered to be more efficient that the Shewhart charts at detecting small shifts in the process mean, particularly if the mean shift is less than 2 sigma. There are several types of CuSum charts, but the easiest to use and the most accurate is considered the tabular CuSum chart and that is the one implemented in this software. The tabular cusum works by accumulating deviations that are above the process mean in one statistic (C+) and accumulating deviations below the process mean in a second statistic (C-). If either statistic (C+ or C-) falls outside of the calculated limits, the process is considered out of control.

Time-Based and Batch-Based SPC Charts

The **QCSPCChart** software further categorizes *Variable Control* as either time- or batch- based. Time-based SPC charts are used when data is collected using a subgroup interval corresponding to a specific time interval. Batch-based SPC charts are used when the data subgroup interval is a sequential batch number that does not correspond to a uniform time interval. The major difference in these two types of SPC charts is the display of the x-axis. Variable control charts that sample using a uniform time interval will generally use a time-based x-axis, with time/date axis labels. Variable control charts that sample based on batches will generally use a numeric-based x-axis, with numeric axis labels.

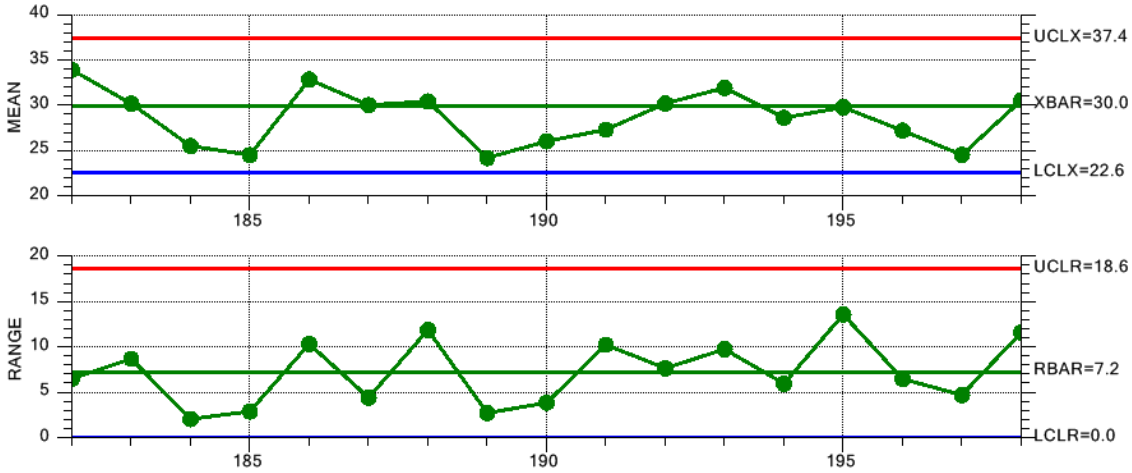
Note: Starting with Revision 2.0, batch control charts can label the x-axis using one of three options: numeric labeling (the original and default mode), time stamp labeling, and user defined string labeling. Since this affects batch control charts, time stamps to not have to be equally spaced, or even sequential

Time-Based Variable Control Chart



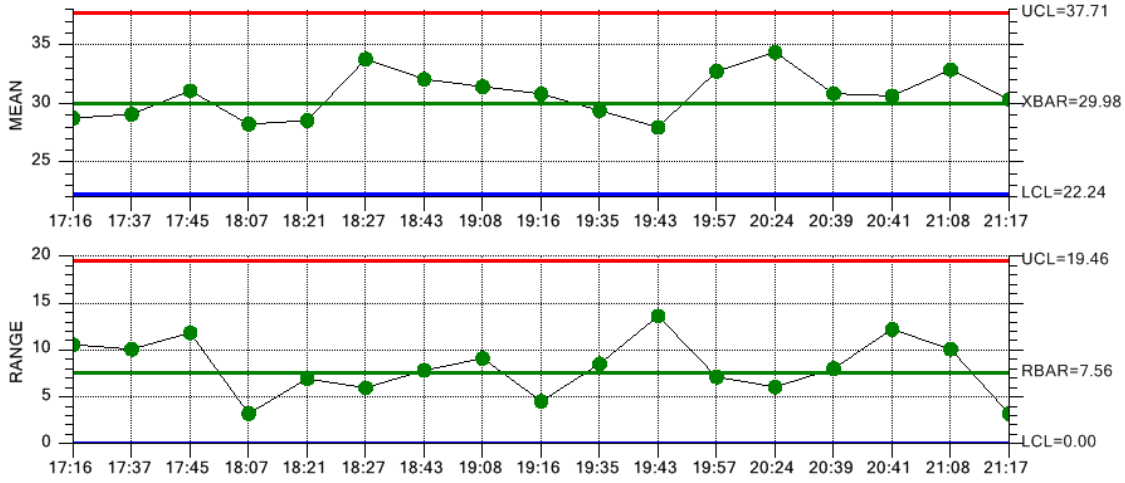
Note the time-based x-axis for both charts.

Batch-Based Variable Control Chart with numeric x-axis



Note the numeric based x-axis for both graphs

Batch-Based Variable Control Chart with time stamp x-axis



Note that even though the time stamp values do not have consistent time interval, the data points are spaced evenly by batch number.

Creating a Variable Control Chart

First, select whether you want to use a time-based variable control chart (use **SPCTimeVariableControlChart**) or a batch-based variable control chart (use **SPCBatchVariableControlChart**). Use that class as the base class for your chart. Since the two classes are so similar and share 95% of all properties in common, only the **SPCTimeVariableControlChart** is discussed in detail, with the differences between the two classes discussed at the end of the chapter. The example below is extracted from the **TimeVariableControlCharts.XBarRChart** example program.

[C#]

```
public class XBarRChart : SPCTimeVariableControlChart
{
    ChartCalendar startTime = new ChartCalendar();

    //  SPC variable control chart type
    int charttype = SPCControlChartData.MEAN_RANGE_CHART;
    // Number of samples per sub group
    int numsamplespersubgroup = 5;
    // Number of data points  in the view
    int numdatapointsinview = 17;
    // The time increment between adjacent subgroups
    int timeincrementminutes = 15;

    public XBarRChart()
    {
        // This call is required by the Windows.Forms Form Designer.
        InitializeComponent();
        // Have the chart fill parent client area
        this.Dock = DockStyle.Fill;
        // Define and draw chart
        InitializeChart();
    }


    public void InitializeChart()
    {
        // Initialize the SPCTimeVariableControlChart
        this.InitSPCTimeVariableControlChart(charttype,
            numsamplespersubgroup, numdatapointsinview, timeincrementminutes);
        .
        .
        .
        this.RebuildChartUsingCurrentData();
    }
}
```

[VB]

```
Public Class XBarRChart
    Inherits com.quinncurtis.spcchartnet.SPCTimeVariableControlChart
    Private startTime As ChartCalendar = New ChartCalendar()
    '  SPC variable control chart type
    Private charttype As Integer = SPCControlChartData.MEAN_RANGE_CHART
    ' Number of samples per sub group
```

```
    Private numsamplespersubgroup As Integer = 5
    ' Number of data points  in the view
    Private numdatapointsinview As Integer = 17
    ' The time increment between adjacent subgroups
    Private timeincrementminutes As Integer = 15

#Region " Windows Form Designer generated code "

    Public Sub New()
        MyBase.New()

        'This call is required by the Windows Form Designer.
        InitializeComponent()

        'Add any initialization after the InitializeComponent() call
        Me.Dock = DockStyle.Fill
        ' Define and draw chart
        InitializeChart()
    End Sub

    .
    .
    .
#End Region


Public Sub InitializeChart()
  ' Initialize the SPCTimeVariableControlChart
  Me.InitSPCTimeVariableControlChart(charttype, numsamplespersubgroup, _
    numdatapointsinview, timeincrementminutes)

  ' Rebuild the chart using the current data and settings
  Me.RebuildChartUsingCurrentData()
End Sub 'InitializeChart
```

SPCTimeVariableControlChart Members

Public Instance Constructors

SPCTimeVariableControlChart	Overloaded. Initializes a new instance of the SPCTimeVariableControlChart class.

Public Instance Methods

InitSPCTimeVariableControlChart	Overloaded. Initialize the class for a specific SPC chart type.
InitSPCTimeCusumControlChart	Overloaded. Initialize the class a cusum chart type.

The control chart type (X-Bar R, Median Range, X-Bar Sigma, Individual Range, EWMA, MA) establishes the variable control charts **InitSPCTimeVariableControlChart** initialization routine. Note that the X-Bar Sigma chart, with a variable subgroup sample size, is initialized using **InitSPCTimeVariableControlChart** with a *charttype* value of MEAN_SIGMA_CHART_VSS. X-Bar Sigma charts with sub groups that use a variable sample size must be updated properly. See the section "Adding New Sample Records to a X-Bar Sigma Chart (Variable Subgroup Sample Size**)"** in the **"**SPC Control Data and Alarm Classes**"** chapter.

SPCTimeVariableControlChart.InitSPCTimeVariableControlChart Method
This initialization method initializes the most important values in the creation of a SPC chart. If you are using the creating a cusum chart (type TABCUSUM_CHART), your can use the similar **InitSPCTimeCusumControlChart** method instead. That version of the Init routine has added parameters for the H and K value of the tabular cusum chart.

[VB]
```
Overloads Public Sub InitSPCTimeVariableControlChart( _
   ByVal charttype As Integer, _
   ByVal numsamplespersubgroup As Integer, _
   ByVal numdatapointsinview As Integer, _
   ByVal timeincrementminutes As Integer _
)
```

```
[C#]
public void InitSPCTimeVariableControlChart(
   int charttype,
   int numsamplespersubgroup,
   int numdatapointsinview,
   int timeincrementminutes
);
```

Parameters

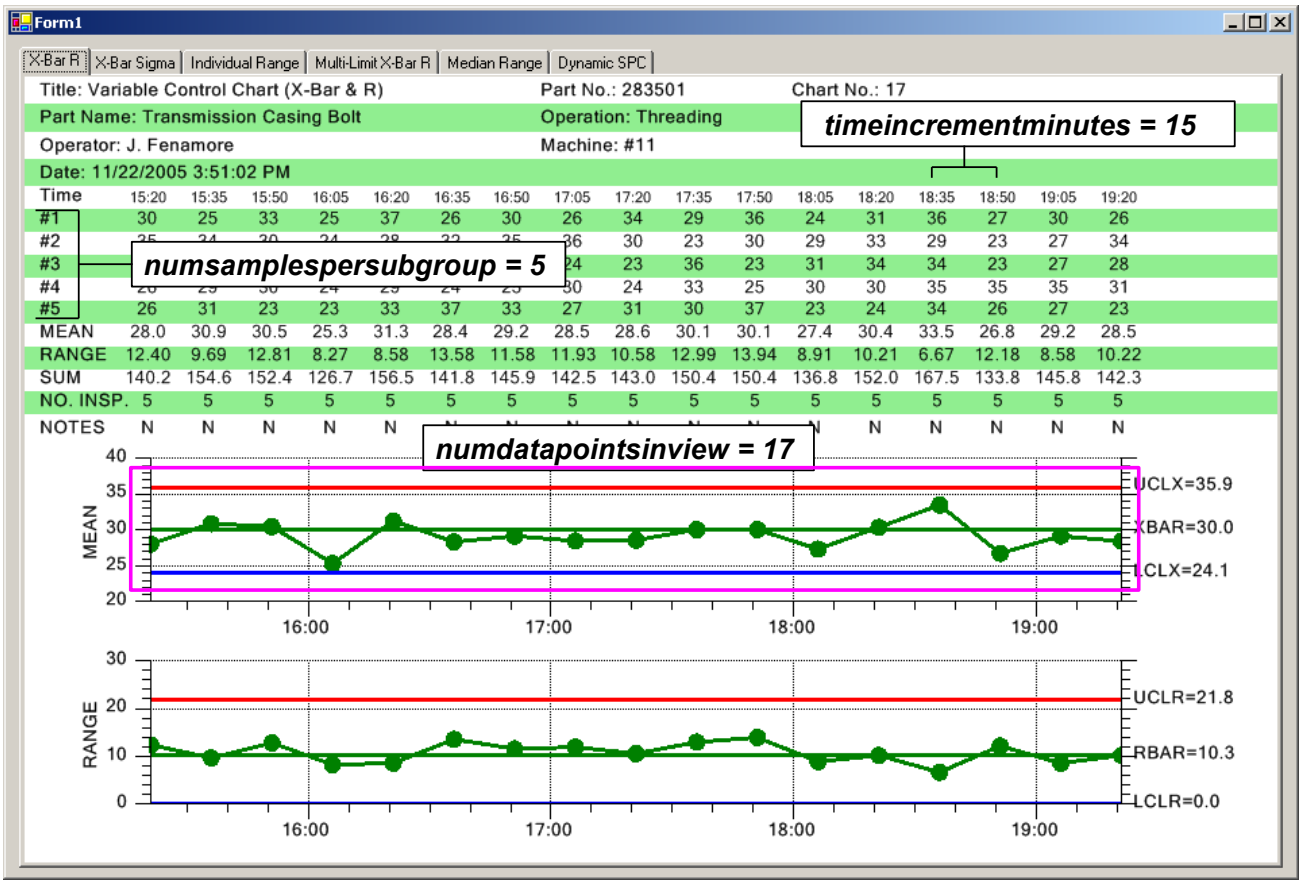
charttype
: The SPC chart type parameter. Use one of the SPCControlChartData SPC chart types: MEAN_RANGE_CHART, MEDIAN_RANGE_CHART, MEAN_SIGMA_CHART, MEAN_SIGMA_CHART_VSS, INDIVIDUAL_RANGE_CHART, EWMA_CHART, MA_CHART, MAMR_CHART, MAMS_CHART and TABCUSUM_CHART.

numsamplespersubgroup
: Specifies the number of samples that make up a sample subgroup.

numdatapointsinview
: Specifies the number of sample subgroups displayed in the graph at one time.

timeincrementminutes
: Specifies the normal time increment between adjacent subgroup samples.

The image below further clarifies how these parameters affect the variable control chart.



Once the Init routine is called, the chart can be further customized using properties inherited from **SPCBaseChart**, described below.

Public Static (Shared) Properties

DefaultChartFontString	Set/Get the default font used in the table display.

Public Instance Constructors

SPCChartBase	Overloaded. Initializes a new instance of the SPCChartBase class.

Public Instance Properties

AutoLogAlarmsAsNotes	Set to true to automatically log alarms in the notes log.
BottomLabelMargin	Get/Set an additional margin, in normalized coordinates, if only the primary graphs is displayed, allowing for the x-axis labels
ChartAlarmEmphasisMode	Set to SPCChartBaseALARM_HIGHLIGHT_SYMBOL to highlight the process variable symbol if an alarm condition exists. Set to Set to SPCChartBase.ALARM_NO_HIGHLIGHT_SYMBOL to

	turn off alarm highlighting.
ChartData	Get the object that holds the descriptive text, sampled and calculated values associated with the control chart.
ChartInitialized	Returns true if the control chart has been initialized at least once.
ChartTable	Get the object that holds the data table information needed to display the data table along with the chart
DefaultControlLimitSigma	Set/Get that SPC control limits are to be calculated using the 3 sigma level standard.
EnableAlarmStatusValues	If set true enables the alarm status row of the chart table.
EnableCategoryValues	If set true enables the category or sample values rows of the data table
EnableDataToolTip	If set true enables data tooltips
EnableInputStringsDisplay	If set true enables the input string rows of the data table
EnableNotes	If set true enables the notes row of the data table
EnableNotesToolTip	If set true enables data tooltips
EnableScrollBar	If set true the scroll bar is added to the bottom of the chart.
EnableTimeValues	If set true enables the time row of the data table
EnableTotalSamplesValues	If set true enables the total of sampled values row of the data table
GraphBottomPos	Get/Set the bottom edge, using normalized coordinates, of the plotting area for the secondary chart
GraphStartPosX	Get/Set the left edge, using normalized coordinates, of the plotting area for both primary and secondary charts
GraphStartPosY1	Get the top edge, using normalized coordinates, of the plotting area for the primary chart
GraphStartPosY2	Get the top edge, using normalized coordinates, of the plotting area for the secondary chart
GraphStopPosX	Get/Set the right edge, using normalized coordinates, of the plotting area for both primary and secondary charts
GraphStopPosY1	Get the bottom edge, using normalized coordinates, of the plotting area for the primary chart
GraphStopPosY2	Get the bottom edge, using normalized coordinates, of the plotting area for the secondary chart
GraphTopTableOffset	Get/Set the offset of the top of the primary chart from the bottom of the data table, using normalized coordinates
HeaderStringsLevel	Set/Get the level of header strings to include in the chart. Use one of the SPCControlChartData header strings constants: HEADER_STRINGS_LEVEL0, HEADER_STRINGS_LEVEL1, HEADER_STRINGS_LEVEL2, or HEADER_STRINGS_LEVEL3
InterGraphMargin	Get/Set the margin, in normalized coordinates, between the

	primary and secondary charts
MultipleMouseListener	Set/Get the MultiMouseListener.
PrimaryChart	Get the object that holds he the chart objects needed to display the primary chart
ScrollBarBottomPosition	Get/Set the bottom edge, using normalized coordinates, of the optional scroll bar
ScrollBarPixelHeight	Get/Set the height of the scrollbar in pixels
SecondaryChart	Get the object that holds he the chart objects needed to display the secondary chart
SPCChartType	Specifies the control chart type: use one of the SPCControlChartData chart type constants: MEAN_RANGE_CHART, MEDIAN_RANGE_CHART, MEAN_SIGMA_CHART, MEAN_SIGMA_CHART_VSS, INDIVIDUAL_RANGE_CHART, EWMA_CHART, MA_CHART, MAMR_CHART, MAMS_CHART, TABCUSUM_CHART, CUSTOM_ATTRIBUTE_CONTROL_CHART, PERCENT_DEFECTIVE_PARTS_CHART, FRACTION_DEFECTIVE_PARTS_CHART, NUMBER_DEFECTIVE_PARTS_CHART, NUMBER_DEFECTS_CHART, NUMBER_DEFECTS_PERUNIT_CHART.
TableAlarmEmphasisMode	Set the table alarm highlighting to one of the SPCChartBase table highlight constants: ALARM_HIGHLIGHT_NONE, ALARM_HIGHLIGHT_TEXT, ALARM_HIGHLIGHT_OUTLINE, ALARM_HIGHLIGHT_BAR
TableStartPosY	Get the top edge, using normalized coordinates, of the SPC chart table
XScaleMode	Set/Get whether the x-axis is time based, or numeric based.

Public Instance Methods

AddAnnotation	Overloaded. Add a simple annotation to a data point in the specified SPC chart.
AutoCalculateControlLimits	Using the current sampled data values, high, target and low control limits are calculated for both primary and secondary charts using an algorithm appropriate to the SPC chart type.
AutoCalculatePrimaryControlLimits	Using the current sampled data values, high, target and low control limits are calculated for the primary chart using an algorithm appropriate to the SPC chart type.
AutoCalculateSecondaryControlLimits	Using the current sampled data values, high, target and low control limits are calculated for

	the primary chart using an algorithm appropriate to the SPC chart type.
AutoScaleChartYRange	Auto-scale the y-range of the SPC chart so that all of the sampled data and chart control limits are within the bounds of the y-axis.
AutoScalePrimaryChartYRange	Auto-scale the y-range of the primary SPC chart so that all of the sampled data and chart control limits are within the bounds of the y-axis.
AutoScaleSecondaryChartYRange	Auto-scale the y-range of the SPC chart so that all of the sampled data and chart control limits are within the bounds of the y-axis.
Copy	Overloaded. Copies the source object.
Draw	Overrides the Draw method of the underlying ChartView class, so that the scroll bar can be properly repositioned if the size of the window changes. The graphics context the chart is drawn to.
InitSPCChartBase	This initialization method initializes the most important values in the creation of a SPC chart.
IsTimeScale	Returns true if the coordinate system has a time based x-axis. The coordinate system of the chart.
MakeControlLinePlot	Draw a control line, either a simple straight line, or a variable control line, for the specified chart.
RebuildChartUsingCurrentData	Rebuild the graph taking into account the most recent data values.
RescaleGraphsToScrollbar	Rescale primary and secondary charts based on the position of the value of the scroll bar. The thumb position of the scroll bar.
ResetSPCChartData	Reset the history buffers of all of the SPC data objects.
UpdateControlLimitLabel	Creates a numeric label of the control limit, and adds the numeric label to the spc chart.
UseNoTable	Specifies to create the primary and secondary charts without a table. Just the charts, chart title and optional histograms.

Adding New Sample Records for Variable Control Charts.

In variable control charts, each data value in the *samples* array represents a specific sample in the sample subgroup. In X-Bar R, X-Bar Sigma, and Median-Range charts, where the sample subgroup size is some fraction of the total production level, there is one value in the *samples*

array for each measurement sample in the sample subgroup interval. If the production level is sixty items per hour, and the sample size is five items per hour, then the graph would be updated once an hour with five items in the *samples* array.

[C#]

```
DoubleArray samples = new DoubleArray(5);
//  ChartCalendar initialized with current  time by default
ChartCalendar timestamp = new ChartCalendar();
// Place sample values in array
samples[0] = 0.121;     // First of five samples
samples[1] = 0.212;     // Second of five samples
samples[2] = 0.322;     // Third of five samples
samples[3] = 0.021;     // Fourth of five samples
samples[4] = 0.133;     // Fifth of five samples

// Add the new sample subgroup to the chart
this.ChartData.AddNewSampleRecord(timestamp, samples);
```

[VB]

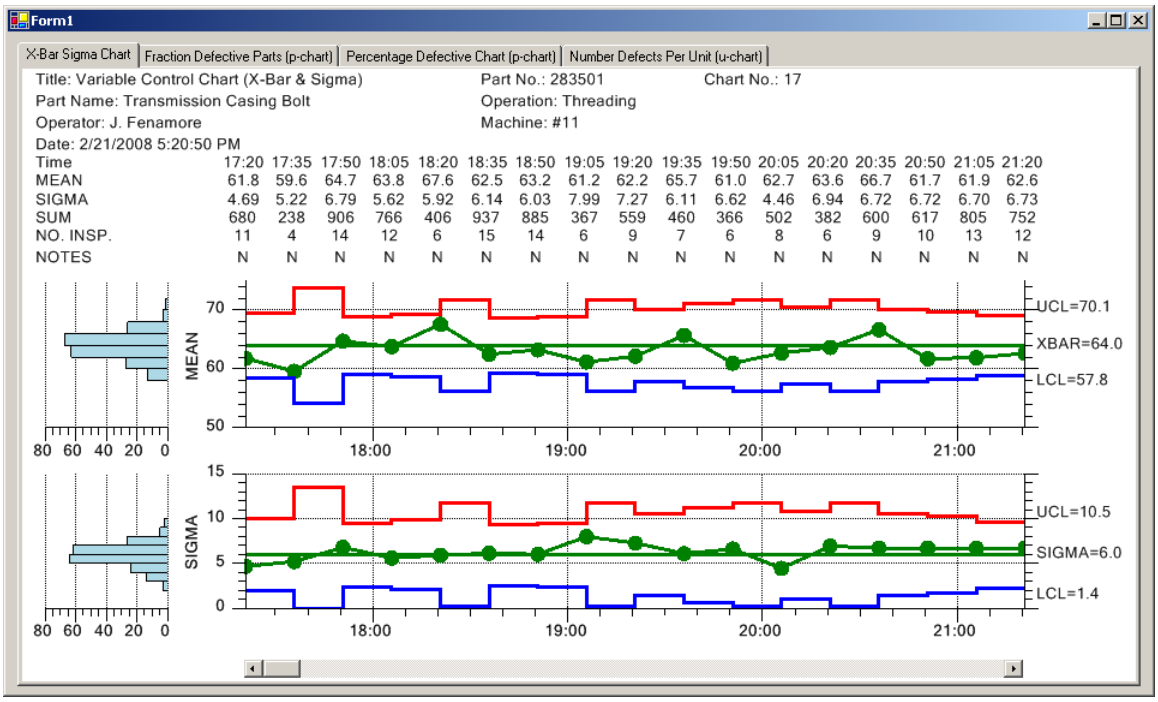
```
Dim samples As DoubleArray = New DoubleArray(5)
'  ChartCalendar initialized with current  time by default
Dim timestamp As ChartCalendar = New ChartCalendar()
' Place sample values in array
samples(0) = 0.121    ' First of five samples
samples(1) = 0.212    ' Second of five samples
samples(2) = 0.322    ' Third of five samples
samples(3) = 0.021    ' Fourth of five samples
samples(4) = 0.133    ' Fifth of five samples

' Add the new sample subgroup to the chart
 Me.ChartData.AddNewSampleRecord(timestamp, samples)
```

In an Individual-Range chart, and EWMA and MA charts that uses rational subgroup sizes of 1, the *samples* array would only have one value for each update. If the production level is sixty items per hour, with 100% sampling, the graph would be updated once a minute, with a single value in the *samples* array.

Updating MEAN_SIGMA_CHART_VSS with a variable number of samples per subgroup

The X-Bar Sigma chart also comes in a version where variable sample sizes are permitted, As in the standard variable control charts, there is one value in the *samples* array for each measurement sample in the sample subgroup interval. The difference is that the length of the *samples* array can change from update to update. It is critically import that the size of the samples array exactly matches the number of samples in the current subgroup

X-Bar Sigma Chart with variable sample size



In this case, the control chart high and low limits vary from sample interval to sample interval, depending on the number of samples in the associated sample subgroup. You can read the sample sizes along the NO.INSP row in the data table above the chart. A low number of samples in the sample subgroup make the band between the high and low limits wider than if a higher number of samples are available. The X-Bar Sigma chart is the only variable control chart that can be used with a variable sample size.

[C#]

```
// GetCurrentSampleSubgroupSize is a fictional method that gets the
// current number of samples in the  sample subgroup. The value of N
// can vary from sample interval to sample interval. You must have a
// valid sample value for each element.

N = GetCurrentSampleSubgroupSize();

// Size array exactly to a length of N
DoubleArray samples = new DoubleArray(N);
//  ChartCalendar initialized with current  time by default
ChartCalendar timestamp = new ChartCalendar();

// Place sample values in array
// You must have a valid sample value for each element of the array size 0..N-1
samples[0] = 0.121;     // First of five samples
samples[1] = 0.212;     // Second of five samples
.
.
.
samples[N-1] = 0.133;       // Last of the samples in the sample subgroup

// Add the new sample subgroup to the chart
this.ChartData.AddNewSampleRecord(timestamp, samples);
```

[VB]

```
' GetCurrentSampleSubgroupSize is a fictional method that gets the
' current number of samples in the  sample subgroup. The value of N
' can vary from sample interval to sample interval. You must have a
' valid sample value for each element.

N = GetCurrentSampleSubgroupSize()

' Size array exactly to a length of N
Dim samples As DoubleArray = New DoubleArray(N)
'  ChartCalendar initialized with current  time by default
Dim timestamp As ChartCalendar = New ChartCalendar()
' Place sample values in array
samples(0) = 0.121    ' First of five samples
samples(1) = 0.212    ' Second of five samples
.
.
.
samples(N-1) = 0.133    ' Last of the samples in the sample subgroup

' Add the new sample subgroup to the chart
 Me.ChartData.AddNewSampleRecord(timestamp, samples)
```

Measured Data and Calculated Value Tables

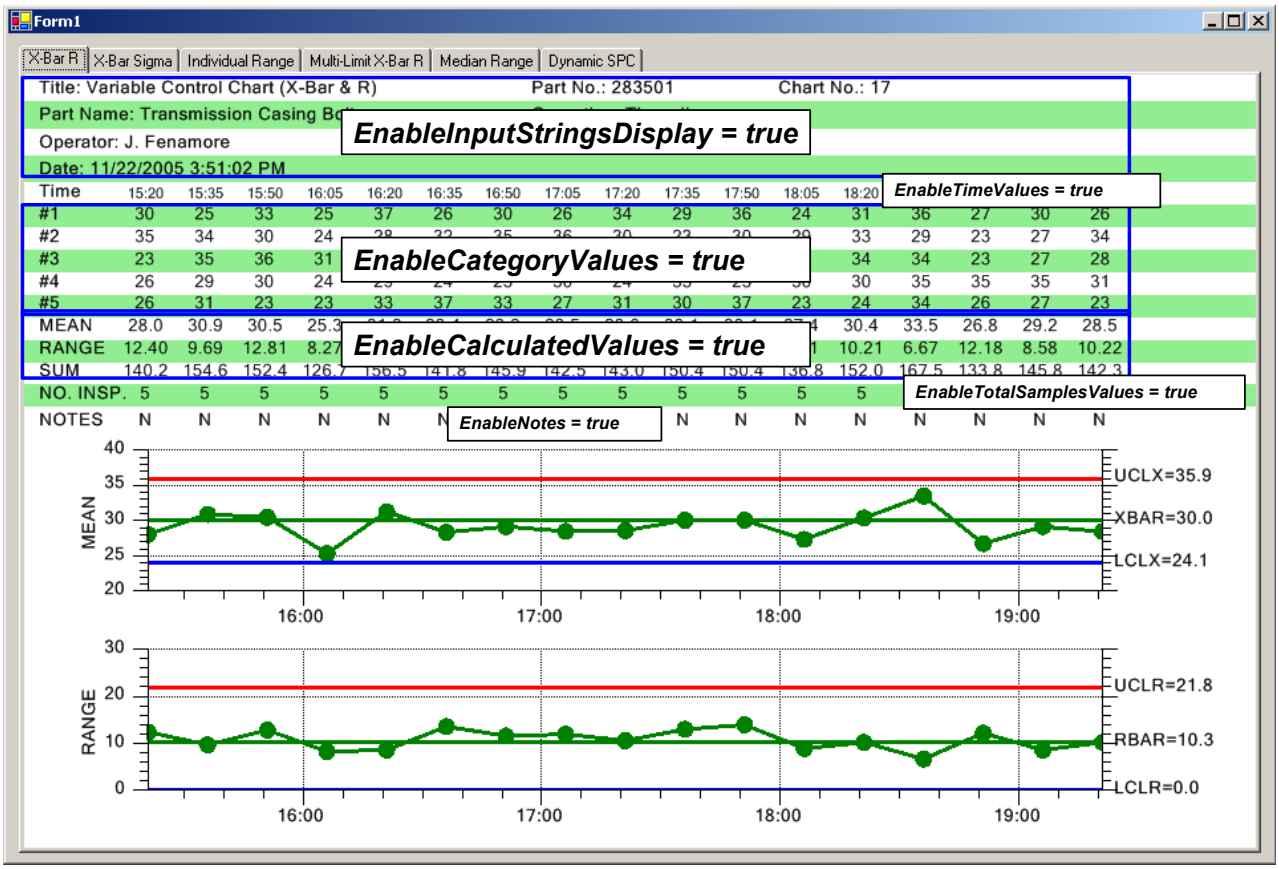
Standard worksheets used to gather and plot SPC data consist of three main parts.

- The first part is the header section, identifying the title of the chart, the monitored process, the machine operator, part number and other important information specific to the chart.
- The second part is the measurement data recording and calculation section, organized as a table where the sample data and calculated values are recorded in a neat, readable fashion.
- The third part plots the calculated SPC values for the sample group variables as a SPC chart.

The chart includes options that enable the programmer to customize and automatically include header information along with a table of the measurement and calculated data, in the SPC chart.

The following properties enable sections of the chart header and table:
:

EnableInputStringsDisplay
EnableCategoryValues
EnableCalculatedValues
EnableTotalSamplesValues
EnableNotes
EnableTotalSamplesValues
EnableTimeValues
EnableProcessCapabilityValues


Form1
X-Bar R
X-Bar Sigma
Individual Range
Multi-Limit X-Bar R
Median Range
Dynamic SPC
Title: Variable Control Chart (X-Bar & R)
Part No.: 283501
Chart No.: 17
Part Name: Transmission Casing Bo
Operator: J. Fenamore
Date: 11/22/2005 3:51:02 PM
EnableInputStringsDisplay = true
EnableTimeValues = true
EnableCategoryValues = true
EnableCalculatedValues = true
EnableTotalSamplesValues = true
EnableNotes = true
Time 15:20 15:35 15:50 16:05 16:20 16:35 16:50 17:05 17:20 17:35 17:50 18:05 18:20
#1 30 25 33 25 37 26 30 26 34 29 36 24 31 36 27 30 26
#2 35 34 30 24 33 29 23 27 34
#3 23 35 36 31 34 34 23 27 28
#4 26 29 30 24 30 35 35 35 31
#5 26 31 23 23 33 37 33 27 31 30 37 23 24 34 26 27 23
MEAN 28.0 30.9 30.5 25.3 30.4 33.5 26.8 29.2 28.5
RANGE 12.40 9.69 12.81 8.27 10.21 6.67 12.18 8.58 10.22
SUM 140.2 154.6 152.4 126.7 152.0 167.5 133.8 145.8 142.3
NO. INSP. 5 5 5 5 5 5 5 5 5 5 5 5 5
NOTES N N N N N N N N N N N N N
MEAN
40
35
30
25
20
16:00
17:00
18:00
19:00
UCLX=35.9
XBAR=30.0
LCLX=24.1
RANGE
30
20
10
0
UCLR=21.8
RBAR=10.3
LCLR=0.0

In the program the code looks like the following code extracted from the TimeVariableControlCharts.XBarRChart example program

[C#]

```
// Change the default horizontal position and width of the chart
this.GraphStartPosX = 0.1; // start here
this.GraphStopPosX = 0.875;  // end here

// Set the strings used in the header section of the table
this.ChartData.Title = "Variable Control Chart (X-Bar & R)";
this.ChartData.PartNumber = "283501";
this.ChartData.ChartNumber="17";
this.ChartData.PartName= "Transmission Casing Bolt";
this.ChartData.Operation = "Threading";
this.ChartData.SpecificationLimits="";
this.ChartData.TheOperator="J. Fenamore";
this.ChartData.Machine="#11";
this.ChartData.Gage="#8645";
this.ChartData.UnitOfMeasure = "0.0001 inch";
this.ChartData.ZeroEquals="zero";
this.ChartData.DateString = DateTime.Now.ToString();
this.ChartData.NotesMessage = "Control limits prepared May 10";
this.ChartData.NotesHeader = "NOTES"; // row header
    // Set initial scale of the y-axis of the mean chart
// If you are calling AutoScalePrimaryChartYRange this isn't really needed
this.PrimaryChart.MinY = 0;
this.PrimaryChart.MaxY = 40;
```

```
// Set initial scale of the y-axis of the range chart
// If you are calling AutoScaleSecondaryChartYRange this isn't really needed
this.SecondaryChart.MinY = 0;
this.SecondaryChart.MaxY = 40;

// Display the Sampled value rows of the table
this.EnableInputStringsDisplay= true;
// Display the Sampled value rows of the table
this.EnableCategoryValues= true;
// Display the Calculated value rows of the table
this.EnableCalculatedValues= true;
// Display the total samples per subgroup value row
this.EnableTotalSamplesValues= true;
// Display the Notes row of the table
this.EnableNotes= true;
// Display the time stamp row of the table
this.EnableTimeValues = true;
```

[VB]

```
' Change the default horizontal position and width of the chart
Me.GraphStartPosX = 0.1 ' start here
Me.GraphStopPosX = 0.875 ' end here
' Set the strings used in the header section of the table
Me.ChartData.Title = "Variable Control Chart (X-Bar & R)"
Me.ChartData.PartNumber = "283501"
Me.ChartData.ChartNumber = "17"
Me.ChartData.PartName = "Transmission Casing Bolt"
Me.ChartData.Operation = "Threading"
Me.ChartData.SpecificationLimits = ""
Me.ChartData.TheOperator = "J. Fenamore"
Me.ChartData.Machine = "#11"
Me.ChartData.Gage = "#8645"
Me.ChartData.UnitOfMeasure = "0.0001 inch"
Me.ChartData.ZeroEquals = "zero"
Me.ChartData.DateString = DateTime.Now.ToString()
Me.ChartData.NotesMessage = "Control limits prepared May 10"
Me.ChartData.NotesHeader = "NOTES" ' row header
' Set initial scale of the y-axis of the mean chart
' If you are calling AutoScalePrimaryChartYRange this isn't really needed
Me.PrimaryChart.MinY = 0
Me.PrimaryChart.MaxY = 40

' Set initial scale of the y-axis of the range chart
' If you are calling AutoScaleSecondaryChartYRange this isn't really needed
Me.SecondaryChart.MinY = 0
Me.SecondaryChart.MaxY = 40

' Display the Sampled value rows of the table
Me.EnableInputStringsDisplay = True
' Display the Sampled value rows of the table
Me.EnableCategoryValues = True
' Display the Calculated value rows of the table
Me.EnableCalculatedValues = True
' Display the total samples per subgroup value row
Me.EnableTotalSamplesValues = True
' Display the Notes row of the table
Me.EnableNotes = True
' Display the time stamp row of the table
Me.EnableTimeValues = True
```

Process Capability Ratios and Process Performance Indices

The data table also displays any process capability statistics that you want to see. The software supports the calculation and display of the Cp, Cpl, Cpu, Cpk, Cpm, Pp, Ppu, Ppl, and Ppk process capability statistics.

In order to display process capability statistics you must first specify the process specification limits that you want the calculations based on. These are not the high and low SPC control limits calculate by this software; rather they externally calculated limits based on the acceptable tolerances allowed for the process under measure. Set the lower specification limit (LSL) and upper specification limit (USL) using the **ChartData.ProcessCapabilityLSLValue** and **ChartData.ProcessCapabilityUSLValue** properties of the chart. The code below is from the TimeVariableControlCharts.XBarRChart example.

```
this.ChartData.ProcessCapabilityLSLValue = 27;
this.ChartData.ProcessCapabilityUSLValue = 35;
```

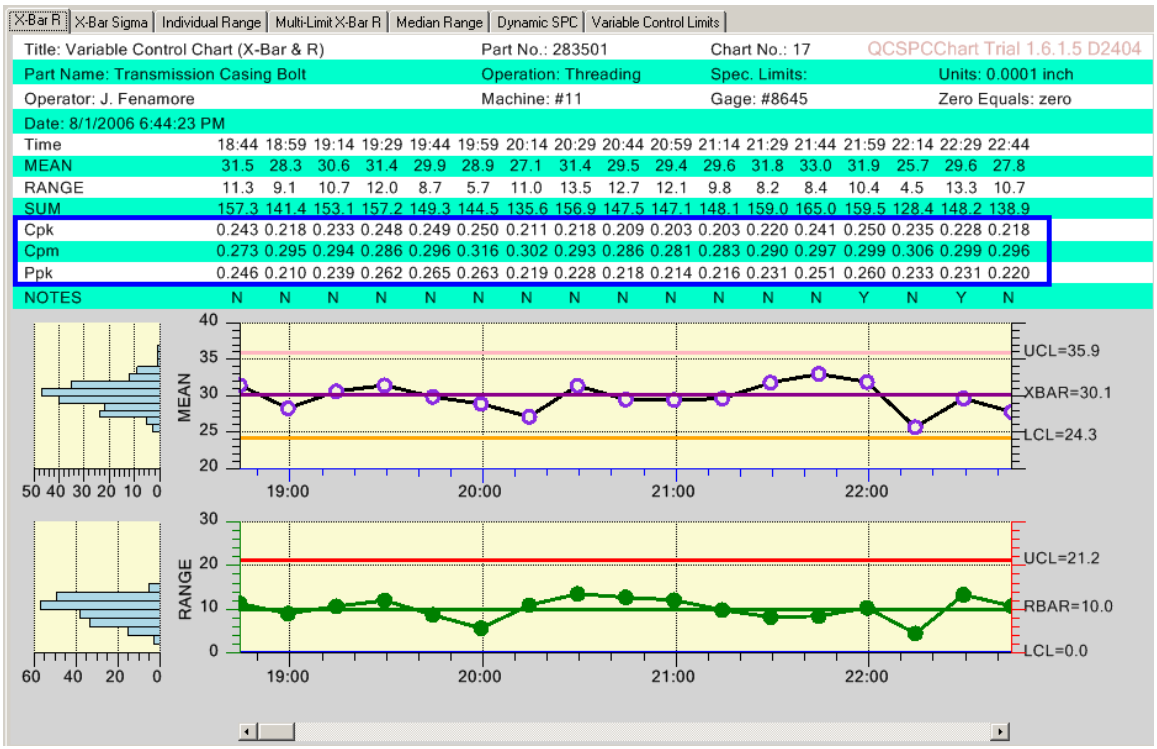
Use the **ChartData.addProcessCapabilityValue** method to specify exactly which process capability statistics you want to see in the table. Use one of the **SPCProcessCapabilityRecord** constants below to specify the statistics that you want displayed.

```
SPC_CP_CALC       Constant value Cp calculation
SPC_CPL_CALC      Constant value Cpl calculation.
SPC_CPU_CALC      Constant value Cpu calculation.
SPC_CPK_CALC      Constant value Cpk calculation.
SPC_CPM_CALC      Constant value Cpm calculation.
SPC_PP_CALC       Constant value Pp calculation.
SPC_PPL_CALC      Constant value Ppl calculation.
SPC_PPU_CALC      Constant value Ppu calculation.
SPC_PPK_CALC      Constant value PPK calculation.
```

The code below is from the TimeVariableControlCharts.XBarRChart example.

```
this.ChartData.AddProcessCapabilityValue(SPCProcessCapabilityRecord.SPC_CPK_CALC);
this.ChartData.AddProcessCapabilityValue(SPCProcessCapabilityRecord.SPC_CPM_CALC);
this.ChartData.AddProcessCapabilityValue(SPCProcessCapabilityRecord.SPC_PPK_CALC);
```

This selection will add three rows to the data table, one row each for the Cpk, Cpm and Ppk process capability statistics. Once these steps are carried out, the calculation and display of the statistics is automatic.



Formulas Used in Calculating the Process Capability Ratios

The formulas used in calculating the process capability statistics vary. We use the formulas found in the textbook. “Introduction to Statistical Quality Control” by Douglas C. Montgomery, John Wiley and Sons, Inc. 2001.

SPC Control Chart Nomenclature

USL = Upper Specification Limit

LSL = Lower Specification Limit

Tau = Midpoint between USL and LSL = ½ * (LSL + USL)

=

X = XDoubleBar - Mean of sample subgroup means (also called the grand average)

$\bar{R}$ = RBar – Mean of sample subgroup ranges

S = Sigma – sample standard deviation – all samples from all subgroups are used to calculate the standard deviation S.

$\overline{S}$ = SigmaBar – Average of sample subgroup sigma's. Each sample subgroup has a calculated standard deviation and the SigmaBar value is the mean of those subgroup standard deviations.

d2 = a constant tabulated in every SPC textbook for various sample sizes.

By convention, the quantity RBar/d2 is used to estimate the process sigma for the Cp, Cpl and Cpu calculations

MINIMUM – a function that returns the lesser of two arguments

SQRT – a function returning the square root of the argument.

Process Capability Ratios (Cp, Cpl, Cpu, Cpk and Cpm)

Cp = (USL – LSL) / (6 * RBar/d2)

Cpl = (XDoubleBar – LSL) / (3 * RBar/d2)

Cpu = (USL - XDoubleBar) / (3 * RBar/d2)

Cpk = MINIMUM (Cpl, Cpu)

Cpm = Cp / (SQRT(1 + V^2)

where

V = (XDoubleBar – Tau) / S

Process Performance Indices (Pp, Ppl, Ppu, Ppk)

Pp = (USL – LSL) / (6 * S)

Ppl = (XDoubleBar – LSL) / (3 * S)

Ppu = (USL - XDoubleBar) / (3 *S)

Ppk = MINIMUM (Ppl, Ppu)

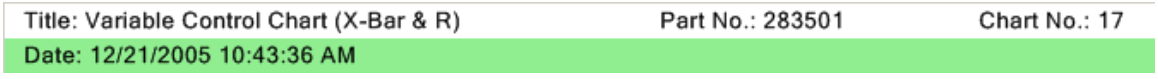
The major difference between the Process Capability Ratios (Cp, Cpl, Cpu, Cpk) and the Process Performance Indices (Pp, Ppl, Ppu, Ppk) is the estimate used for the process sigma. The Process Capability Ratios use the estimate (RBar/d2) and the Process Performance Indices uses the sample standard deviation S. If the process is in control, then Cp vs Pp and Cpk vs Ppk should returns approximately the same values, since both (RBar/d2) and the sample sigma S will be good estimates of the overall process sigma. If the process is NOT in control, then ANSI (American National Standards Institute) recommends that the Process Performance Indices (Pp, Ppl, Ppu, Ppk) be used.

Table Strings

The input header strings display has four sub-levels that display increasing levels of information. The input header strings display level is set using the charts HeaderStringsLevel property. Strings that can be displayed are: Title, PartNumber, ChartNumber, DateString, PartName, Operation, Machine, SpecificationLimits, Gage, UnitOfMeasure, ZeroEquals and DateString. The four levels and the information displayed is listed below:

HEADER_STRINGS_LEVEL0	Display no header information
HEADER_STRINGS_LEVEL1	Display minimal header information: Title, PartNumber, ChartNumber, DateString
HEADER_STRINGS_LEVEL2	Display most header strings: Title, PartNumber, ChartNumber, PartName, Operation, Operator, Machine, DateString
HEADER_STRINGS_LEVEL3	Display all header strings: Title, PartNumber, ChartNumber, DateString, PartName, Operation, Machine, SpecificationLimits, Gage, UnitOfMeasure, ZeroEquals and DateString

The example program TimeVariableControlCharts.XBarRChart demonstrates the use of the **HeaderStringsLevel** property. The example below displays a minimum set of header strings (HeaderStringsLevel = SPCControlChartData.HEADER_STRINGS_LEVEL1).



[C#]

```
// Set the strings used in the header section of the table
```

```
this.ChartData.Title = "Variable Control Chart (X-Bar & R)";
this.ChartData.PartNumber = "283501";
this.ChartData.ChartNumber="17";
this.ChartData.DateString = DateTime.Now.ToString();

this.HeaderStringsLevel = SPCControlChartData.HEADER_STRINGS_LEVEL1;
```

[VB]

```
' Set the strings used in the header section of the table
Me.ChartData.Title = "Variable Control Chart (X-Bar & R)"
Me.ChartData.PartNumber = "283501"
Me.ChartData.ChartNumber = "17"
Me.ChartData.DateString = DateTime.Now.ToString()

Me.HeaderStringsLevel = SPCControlChartData.HEADER_STRINGS_LEVEL1
```

The example below displays a maximum set of header strings (HeaderStringsLevel = SPCControlChartData.HEADER_STRINGS_LEVEL3).

Title: Variable Control Chart (X-Bar & R)	Part No.: 283501	Chart No.: 17	
Part Name: Transmission Casing Bolt	Operation: Threading	Spec. Limits:	Units: 0.0001 inch
Operator: J. Fenamore	Machine: #11	Gage: #8645	Zero Equals: zero
Date: 12/21/2005 10:45:58 AM			

[C#]

```
// Set the strings used in the header section of the table
this.ChartData.Title = "Variable Control Chart (X-Bar & R)";
this.ChartData.PartNumber = "283501";
this.ChartData.ChartNumber="17";
this.ChartData.PartName= "Transmission Casing Bolt";
this.ChartData.Operation = "Threading";
this.ChartData.SpecificationLimits="";
this.ChartData.TheOperator="J. Fenamore";
this.ChartData.Machine="#11";
this.ChartData.Gage="#8645";
this.ChartData.UnitOfMeasure = "0.0001 inch";
this.ChartData.ZeroEquals="zero";
this.ChartData.DateString = DateTime.Now.ToString();
this.HeaderStringsLevel = SPCControlChartData.HEADER_STRINGS_LEVEL3;
```

[VB]

```
' Set the strings used in the header section of the table
Me.ChartData.Title = "Variable Control Chart (X-Bar & R)"
Me.ChartData.PartNumber = "283501"
Me.ChartData.ChartNumber = "17"
Me.ChartData.PartName = "Transmission Casing Bolt"
Me.ChartData.Operation = "Threading"
Me.ChartData.SpecificationLimits = ""
Me.ChartData.TheOperator = "J. Fenamore"
Me.ChartData.Machine = "#11"
Me.ChartData.Gage = "#8645"
Me.ChartData.UnitOfMeasure = "0.0001 inch"
Me.ChartData.ZeroEquals = "zero"
Me.ChartData.DateString = DateTime.Now.ToString()
Me.HeaderStringsLevel = SPCControlChartData.HEADER_STRINGS_LEVEL3
```

The identifying string displayed in front of the input header string can be any string that you want, including non-English language strings. For example, if you want the input header string for the Title to represent a project name:

Project Name: Project XKYZ for PerQuet

Set the properties:

[C#]
```
this.ChartData.Title = "Project XKYZ for PerQuet";
this.ChartData.TitleHeader = "Project Name:";
```

[VB]
```
Me.ChartData.Title = "Project XKYZ for PerQuet"
Me.ChartData.TitleHeader = "Project Name:"
```

Change other header strings using the **ChartData** properties listed below.

- TitleHeader
- PartNumberHeader
- ChartNumberHeader
- PartNameHeader
- OperationHeader
- OperatorHeader
- MachineHeader
- DateHeader
- SpecificationLimitsHeader
- GageHeader
- UnitOfMeasureHeader
- ZeroEqualsHeader
- NotesHeader

Even though the input header string properties have names like Title, PartNumber, ChartNumber, etc., those names are arbitrary. They are really just placeholders for the strings that are placed at the respective position in the table. You can display any combination of strings that you want, rather than the ones we have selected by default, based on commonly used standardized SPC Control Charts.

Table Background Colors

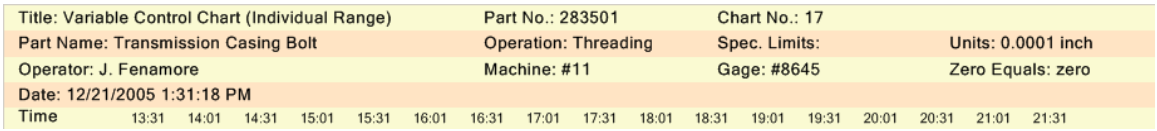
The **ChartTable** property of the chart has some properties that can further customize the chart. The default table background uses the accounting style green-bar striped background. You can change this using the **ChartTable.TableBackgroundMode** property**.** Set the value to one of the TableBackgroundMode constants in the class **SPCGeneralizedTableDisplay**:

TABLE_NO_COLOR_BACKGROUND	Constant specifies that the table does not use a background color.
TABLE_SINGLE_COLOR_BACKGROUND	Constant specifies that the table uses a single color for the background (backgroundColor1)

TABLE_STRIPED_COLOR_BACKGROUND Constant specifies that the table uses horizontal stripes of color for the background (backgroundColor1 and backgroundColor2)

TABLE_SINGLE_COLOR_BACKGROUND_GRIDCELL Constant specifies that the table uses a grid background, with backgroundColor1 the overall background color and backgroundColor2 the color of the grid lines.

Extracted from the TimeVariableControlCharts.IndividualRangeChart example program


Title: Variable Control Chart (Individual Range)
Part No.: 283501
Chart No.: 17
Part Name: Transmission Casing Bolt
Operation: Threading
Spec. Limits:
Units: 0.0001 inch
Operator: J. Fenamore
Machine: #11
Gage: #8645
Zero Equals: zero
Date: 12/21/2005 1:31:18 PM
Time
13:31 14:01 14:31 15:01 15:31 16:01 16:31 17:01 17:31 18:01 18:31 19:01 19:31 20:01 20:31 21:01 21:31

[C#]

```
this.ChartTable.TableBackgroundMode =
    SPCGeneralizedTableDisplay.TABLE_STRIPED_COLOR_BACKGROUND;
this.ChartTable.BackgroundColor1 = Color.Bisque;
this.ChartTable.BackgroundColor2 = Color.LightGoldenrodYellow;
```

[VB]

```
Me.ChartTable.TableBackgroundMode = _
    SPCGeneralizedTableDisplay.TABLE_STRIPED_COLOR_BACKGROUND
Me.ChartTable.BackgroundColor1 = Color.Bisque
Me.ChartTable.BackgroundColor2 = Color.LightGoldenrodYellow
```

Extracted from the TimeVariableControlCharts.MedianRangeChart example program

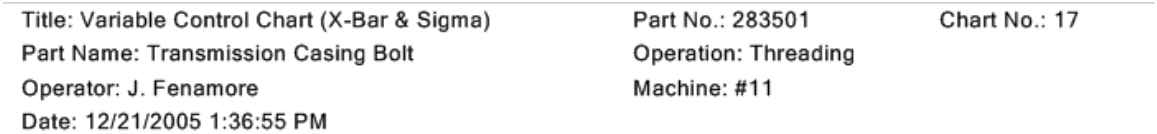
[C#]

```
this.ChartTable.TableBackgroundMode =
    SPCGeneralizedTableDisplay.TABLE_SINGLE_COLOR_BACKGROUND;
this.ChartTable.BackgroundColor1 = Color.LightGray;
```

[VB]

```
Me.ChartTable.TableBackgroundMode = _
    SPCGeneralizedTableDisplay.TABLE_SINGLE_COLOR_BACKGROUND
Me.ChartTable.BackgroundColor1 = Color.LightGray
```

Extracted from the TimeVariableControlCharts.XBarSigma example program



[C#]
```
this.ChartTable.TableBackgroundMode =
       SPCGeneralizedTableDisplay.TABLE_NO_COLOR_BACKGROUND;
```

[VB]
```
Me.ChartTable.TableBackgroundMode = _
       SPCGeneralizedTableDisplay.TABLE_NO_COLOR_BACKGROUND
```

Title: Variable Control Chart (X-Bar & R)						Part No.: 283501				Chart No.: 17							
Part Name: Transmission Casing Bolt						Operation: Threading				Spec. Limits:						Units: 0.0001 inch	
Operator: J. Fenamore						Machine: #11				Gage: #8645						Zero Equals: zero	
Date: 4/15/2008 4:53:41 PM																	
TIME	16:53	17:08	17:23	17:38	17:53	18:08	18:23	18:38	18:53	19:08	19:23	19:38	19:53	20:08	20:23	20:38	20:53
MEAN	29.7	30.6	31.5	30.3	31.1	28.6	28.8	29.4	28.9	31.0	29.0	28.1	32.8	30.2	29.5	30.3	32.5
RANGE	10.8	11.4	7.2	10.1	11.4	10.0	9.9	7.6	11.5	9.7	11.3	10.8	9.5	11.8	12.6	9.6	8.5
SUM	148.7	152.9	157.5	151.7	155.6	142.9	143.9	147.1	144.3	154.8	144.9	140.4	163.8	151.2	147.3	151.4	162.4
Cpk	0.2	0.2	0.3	0.3	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Cpm	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Ppk	0.2	0.2	0.3	0.3	0.3	0.3	0.3	0.3	0.2	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.3
ALARM	- | -	- | -	- | -	- | -	- | -	- | -	- | -	- | -	- | -	- | -	- | -	- | -	- | -	- | -	- | -	- | -	- | -	- | -
NOTES	Y	Y	N	Y	N	N	N	N	N	N	N	Y	Y	N	N	N	N

[C#]
```
this.ChartTable.TableBackgroundMode =
    SPCGeneralizedTableDisplay.TABLE_SINGLE_COLOR_BACKGROUND_GRIDCELL;
this.ChartTable.BackgroundColor1 = Color.White;
this.ChartTable.BackgroundColor2 = Color.Gray;
```
[VB]
```
Me.ChartTable.TableBackgroundMode =
SPCGeneralizedTableDisplay.TABLE_SINGLE_COLOR_BACKGROUND_GRIDCELL
Me.ChartTable.BackgroundColor1 = Color.White
Me.ChartTable.BackgroundColor2 = Color.Gray
```

Table and Chart Fonts

There are a large number of fonts that you have control over, both the fonts in the table and the fonts in the chart. The programmer can select a default font (as in the case of non-US character set), or select individual fonts for different elements of the table and charts.

Table Fonts

The table fonts are accessed through the charts **ChartTable** property. Below is a list of accessible table fonts:

Property Name	**Description**
TimeLabelFont	The font used in the display of time values in the table.
SampleLabelFont	The font used in the display of sample numeric values in the table.
CalculatedLabelFont	The font used in the display of calculated values in the table.
StringLabelFont	The font used in the display of header string values in the table.
NotesLabelFont	The font used in the display of notes values in the table.

Extracted from the example BatchVariableControlCharts.BatchIndividualRangeChart

[C#]
```
this.ChartTable.SampleLabelFont = new Font("Times", 12, FontStyle.Regular);
```

[VB]
```
Me.ChartTable.SampleLabelFont = new Font("Times", 12, FontStyle.Regular)
```

The **ChartTable** class has a static property, **SPCGeneralizedTableDisplay.DefaultTableFont**, that sets the default Font. Use this if you want to establish a default font for all of the text in a table. This static property must be set BEFORE the charts **Init** routine.

Extracted from the example BatchVariableControlCharts.BatchIndividualRangeChart

[C#]
```
SPCGeneralizedTableDisplay.DefaultTableFont =
    new Font("Microsoft Sans Serif", 10, FontStyle.Regular);
// Initialize the SPCBatchVariableControlChart
this.InitSPCBatchVariableControlChart(charttype, numsamplespersubgroup,
       numdatapointsinview);
.
.
.
```

[VB]
```
SPCGeneralizedTableDisplay.DefaultTableFont = _
    new Font("Microsoft Sans Serif", 10, FontStyle.Regular)
' Initialize the SPCBatchVariableControlChart
Me.InitSPCBatchVariableControlChart(charttype, numsamplespersubgroup, _
    numdatapointsinview)
.
.
.
```

Chart Fonts

There are default chart fonts that are static objects in the **SPCChartObjects** class. They establish the default fonts for related chart objects and if you change them they need to be set before the first charts Init.. call. Since these properties are static, any changes to them will apply to the program as a whole, not just the immediate class.

AxisLabelFont	The font used to label the x- and y- axes.
AxisTitleFont	The font used for the axes titles.
HeaderFont	The font used for the chart title.
SubheadFont	The font used for the chart subhead.
ToolTipFont	The tool tip font.
AnnotationFont	The annotation font.
ControlLimitLabelFont	The font used to label the control limits

Extracted from the example TimeVariableControlCharts.DynamicXBarRChart

[C#]
```
SPCChartObjects.AxisTitleFont = new Font("Times", 12, FontStyle.Regular);
SPCChartObjects.ControlLimitLabelFont = new Font("Times", 10, FontStyle.Regular);

this.InitSPCTimeVariableControlChart(charttype,
       numsamplespersubgroup, numdatapointsinview, timeincrementminutes);
```
[VB]
```
SPCChartObjects.AxisTitleFont = new Font("Times", 12, FontStyle.Regular)
```

```
SPCChartObjects.ControlLimitLabelFont = new Font("Times", 10, FontStyle.Regular)

Me.InitSPCTimeVariableControlChart(charttype,  _
       numsamplespersubgroup, numdatapointsinview, timeincrementminutes)
```

The chart class has a static property, **DefaultTableFont**, that sets the default Font string. Since the chart fonts all default to different sizes, the default font is defined using a string specifying the name of the font. This static property must be set BEFORE the charts **Init** routine.

Extracted from the example Extracted from the example TimeVariableControlCharts.DynamicXBarRChart

[C#]

```
SPCTimeVariableControlChart.DefaultChartFontString = "Times";
this.InitSPCTimeVariableControlChart(charttype,
       numsamplespersubgroup, numdatapointsinview, timeincrementminutes);.
.
.
```

[VB]

```
SPCTimeVariableControlChart.DefaultChartFontString = "Times"
Me.InitSPCTimeVariableControlChart(charttype,  _
       numsamplespersubgroup, numdatapointsinview, timeincrementminutes).
```

Table and Chart Templates

All of the strings displayed in the table and charts use a template unique to the string type. Numeric strings use a **NumericLabel** template, time/date strings use a time **TimeLabel** template, and so on. These templates permit the programmer to customize the display of the strings. Listed below are the various templates.

SPCChartObjects (Accessed in the charts PrimaryChart and SecondaryChart properties)

Property	Type	Description
XValueTemplate	NumericLabel	The x-value template for the data tooltip.
YValueTemplate	NumericLabel	The y-value template for the data tooltip.
XTimeValueTemplate	TimeLabel	x-value template for the data tooltip.
TextTemplate	ChartText	The text template for the data tooltip.

SPCGeneralizedTableDisplay (Accessed in the charts ChartTable property)

Property	Type	Description
TimeItemTemplate	TimeLabel	The TimeLabel object used as a template for displaying time values in the table.
SampleItemTemplate	NumericLabel	The NumericLabel object used as a template for displaying the sample values in the table.
CalculatedItemTemplate	NumericLabel	The NumericLabel object used as a template for displaying calculated values in the table.
StringItemTemplate	StringLabel	The StringLabel object used as a template for displaying string values in the table.

NotesItemTemplate	NotesLabel	The NotesLabel object used as a template for displaying string values in the table.

The most common use for these templates is to set the color attributes of a class of objects, or decimal precision of a numeric string.

```
this.ChartTable.SampleItemTemplate.LineColor = Color.Red;
```

SPC Charts without a Table

If you don't want any of the items we have designated table itmes, just call the **UseNoTable** method. That method removes all of the table items, and displays the primary and/or secondary charts with a simple title and optional histograms.

This initialization method initializes the most important values in the creation of a SPC chart.

[VB]
```
Overloads Public Sub UseNoTable ( _
   ByVal primarychart As Boolean, _
   ByVal secondarychart As Boolean, _
   ByVal histograms As Boolean, _
   ByVal title As String, _
)
```

[C#]
```
public void UseNoTable (
   bool primarychart,
   bool secondarychart,
   bool histograms,
   String title
);
```

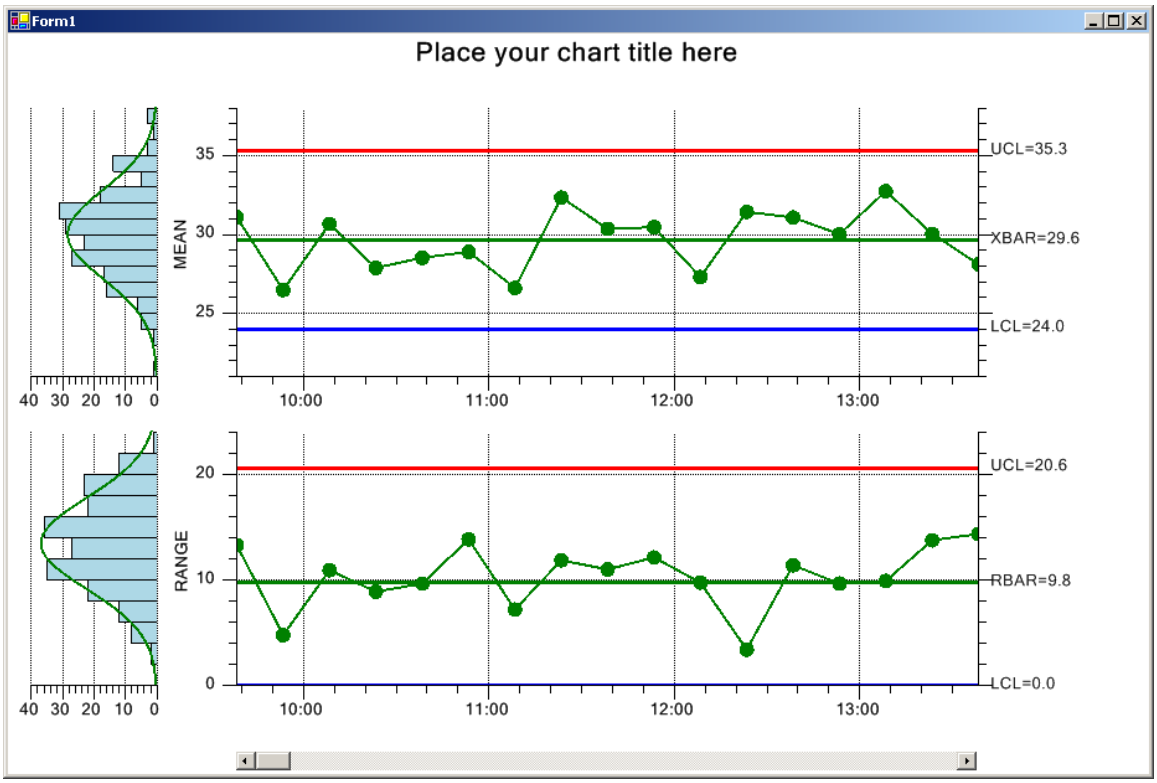
Parameters

primarychart
: Set to true to display primary chart.

secondarychart
: Set to true to display secondary chart.

histograms
: Set to true to display chart histograms

title
: Specifies the title for the charts



Extracted from the exaple program SPCApplication1.

[C#]

```
public void InitializeChart()
{
    //  SPC variable control chart type
    int charttype = SPCControlChartData.MEAN_RANGE_CHART;
// Number of datapoints in the view
    int numdatapointsinview = 17;


    // Initialize the SPCTimeVariableControlChart
    this.InitSPCTimeVariableControlChart(charttype,  numsamplespersubgroup,
                numdatapointsinview, timeincrementminutes);

    this.UseNoTable(true,true,true, "Place your chart title here");

    this.EnableScrollBar = true;
    this.ChartAlarmEmphasisMode= SPCChartBase.ALARM_HIGHLIGHT_SYMBOL;

    // training data
    SimulateData(50, 30, 10);

// Calculate the SPC control limits for both graphs of the current SPC chart (X-Bar R)
    this.AutoCalculateControlLimits();

    // New data added after limits calculated
    SimulateData(150, 30, 15);

    // Scale the y-axis of the X-Bar chart to display all data and control limits
    this.AutoScalePrimaryChartYRange();
    // Scale the y-axis of the Range chart to display all data and control limits
    this.AutoScaleSecondaryChartYRange();
    // Rebuild the chart using the current data and settings
    this.RebuildChartUsingCurrentData();
}
```

[VB]
```
Public Sub InitializeChart()
    '  SPC variable control chart type
    Dim charttype As Integer = SPCControlChartData.MEAN_RANGE_CHART

    ' Number of datapoints in the view
    Dim numdatapointsinview As Integer = 17


     ' Initialize the SPCTimeVariableControlChart
     Me.InitSPCTimeVariableControlChart(charttype, numsamplespersubgroup,
numdatapointsinview, timeincrementminutes)

     Me.UseNoTable(True, True, True, "Place your chart title here")

     Me.EnableScrollBar = True

     Me.ChartAlarmEmphasisMode = SPCChartBase.ALARM_HIGHLIGHT_SYMBOL

     ' Training data to establish limits
     SimulateData(50, 30, 10)
     Me.AutoCalculateControlLimits()

     ' New data
     SimulateData(50, 30, 15)

     ' Scale the y-axis of the X-Bar chart to display all data and control limits
     Me.AutoScalePrimaryChartYRange()
     ' Scale the y-axis of the Range chart to display all data and control limits
     Me.AutoScaleSecondaryChartYRange()
     ' Rebuild the chart using the current data and settings
     Me.RebuildChartUsingCurrentData()
End Sub 'InitializeChart
```

Chart Position

If the SPC chart does not include frequency histograms on the left (they take up about 20% of the available chart width), you may want to adjust the left and right edges of the chart using the **GraphStartPosX** and **GraphStopPlotX** properties to allow for more room in the display of the data. This also affects the table layout, because the table columns must line up with the chart data points.

[C#]
```
this.GraphStartPosX = 0.1; // start here
this.GraphStopPosX = 0.875;  // end here
```

[VB]
```
Me.GraphStartPosX = 0.1 ' start here
Me.GraphStopPosX = 0.875 ' end here
```

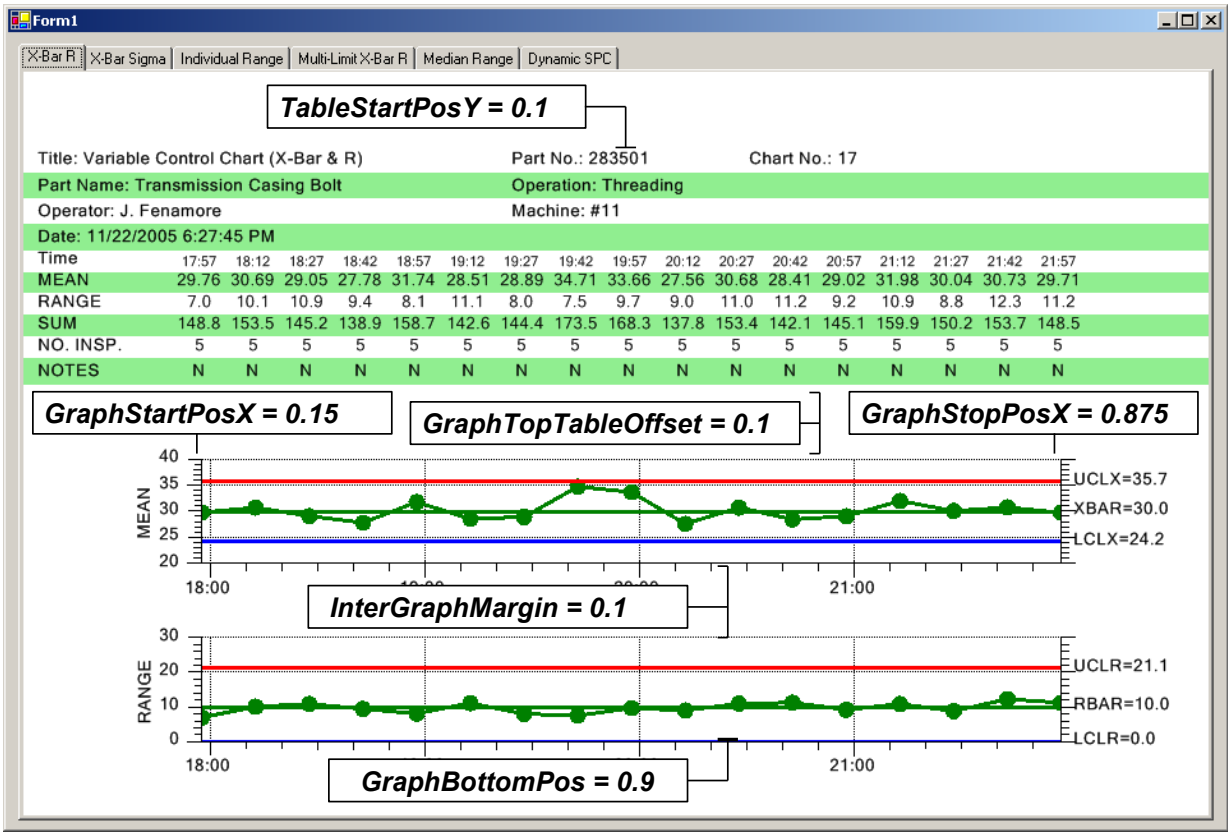
There is not much flexibility positioning the top and bottom of the chart. Depending on the table items enabled, the table starts at the position defined the **TableStartPosY** property, and continues until all of the table items are displayed. It then offsets the top of the primary chart with respect to the bottom of the table by the value of the property **GraphTopTableOffset**. The top of the secondary chart offsets from the bottom of the primary chart by the amount of the

property **InterGraphMargin**. The value of the property **GraphBottomPos** defines the bottom of the graph. The default values for these properties are:

[C#]
```
this.TableStartPosY = 0.00;
this.GraphTopTableOffset = 0.02;
this.InterGraphMargin = 0.075;
this.GraphBottomPos = 0.925;
```

[VB]
```
Me.TableStartPosY = 0.00
Me.GraphTopTableOffset = 0.02
Me.InterGraphMargin = 0.075
Me.GraphBottomPos = 0.925
```

The picture below uses different values for these properties in order to emphasize the affect that these properties have on the resulting chart.



SPC Control Limits

There are two ways to set the SPC control limit for a chart. The first explicitly sets the limits to values that you calculate on your own, because of some analysis that a quality engineer does on previously collected data. The second auto-calculates the limits using the algorithms supplied in this software.

The quick way to set the limit values and limit strings is to use the charts **ChartData.SetControlLimitValues** and **ChartData.SetControlLimitStrings** methods. This method only works for the default +-3-sigma level control limits, and not any others you may have added using the charts **AddAdditionalControlLimit** method discussed in the *Multiple Control Limits* section. The data values in the *controllimitvalues* and *controllimitstrings* arrays used to pass the control limit information must be sorted in the following order:

[SPC_PRIMARY_CONTROL_TARGET,
SPC_PRIMARY_LOWER_CONTROL_LIMIT,
SPC_PRIMARY_UPPER_CONTROL_LIMIT,
SPC_SECONDARY_CONTROL_TARGET,
SPC_SECONDARY_LOWER_CONTROL_LIMIT,
SPC_SECONDARY_UPPER_CONTROL_LIMIT]

Example code extracted from **the TimeVariableControlsCharts.MedianRangeChart** example program.

[C#]
```
double [] controllimitvalues = {42, 30, 53, 10, 0, 22};
this.ChartData.SetControlLimitValues(controllimitvalues);

string [] controllimitstrings = {"XBAR","LCL", "UCL","RBAR","LCL","UCL"};
this.ChartData.SetControlLimitStrings(controllimitstrings);
```

[VB]
```
Dim controllimitvalues() As Double = {30, 24, 36, 10, 0, 22}
Me.ChartData.SetControlLimitValues(controllimitvalues)

Dim controllimitstrings() As String = {"XBAR", "LCL", "UCL",
"RBAR", "LCL", "UCL"}
Me.ChartData.SetControlLimitStrings(controllimitstrings)
```

You can also set the control limit values and control limit text one value at a time using the **ChartData.SetControlLimitValue** and **ChartData.SetControlLimitString** methods.

A more complicated way to set the control limits explicitly is to first grab a reference to the **SPCControlLimitRecord** for a given control limit, and then change the value of that control limit, and the control limit text, if desired. The example below sets the control limit values and text for the three control limits (target value, upper control limit, and lower control limit) of the primary chart, and the three control limit values for the secondary chart.

[C#]
```
//target control limit primary chart
SPCControlLimitRecord primarytarget =
    ChartData.GetControlLimitRecord(SPCChartObjects.SPC_PRIMARY_CONTROL_TARGET);
primarytarget.ControlLimitValue = 30;
primarytarget.ControlLimitText = "XBAR";

//lower control limit primary chart
SPCControlLimitRecord primarylowercontrollimit =
ChartData.GetControlLimitRecord(SPCControlChartData.SPC_PRIMARY_LOWER_CONTROL_LIMIT);
primarylowercontrollimit.ControlLimitValue = 24;
primarylowercontrollimit.ControlLimitText = "LCL";

//upper control limit primary chart
SPCControlLimitRecord primaryuppercontrollimit =
```

```
ChartData.GetControlLimitRecord(SPCControlChartData.SPC_PRIMARY_UPPER_CONTROL_LIMIT);
primaryuppercontrollimit.ControlLimitValue = 36;
primaryuppercontrollimit.ControlLimitText = "UCL";

// Set control limits for secondary chart

//target control limit secondary chart
SPCControlLimitRecord secondarytarget =
ChartData.GetControlLimitRecord(SPCControlChartData.SPC_SECONDARY_CONTROL_TARGET);
secondarytarget.ControlLimitValue = 10;
secondarytarget.ControlLimitText = "RBAR";

//lower control limit secondary chart
SPCControlLimitRecord secondarylowercontrollimit =
ChartData.GetControlLimitRecord(SPCControlChartData.SPC_SECONDARY_LOWER_CONTROL_LIMIT);
secondarylowercontrollimit.ControlLimitValue = 0;
secondarylowercontrollimit.ControlLimitText = "LCL";

//upper control limit secondary chart
SPCControlLimitRecord secondaryuppercontrollimit =
ChartData.GetControlLimitRecord(SPCControlChartData.SPC_SECONDARY_UPPER_CONTROL_LIMIT);
secondaryuppercontrollimit.ControlLimitValue = 22;
secondaryuppercontrollimit.ControlLimitText = "UCL";
```

[VB]

```
'target control limit primary chart
Dim primarytarget As SPCControlLimitRecord = _
  ChartData.GetControlLimitRecord(SPCControlChartData.SPC_PRIMARY_CONTROL_TARGET)
primarytarget.ControlLimitValue = 30
primarytarget.ControlLimitText = "XBAR"

'lower control limit primary chart
Dim primarylowercontrollimit As SPCControlLimitRecord = _
  ChartData.GetControlLimitRecord(SPCControlChartData.SPC_PRIMARY_LOWER_CONTROL_LIMIT)
primarylowercontrollimit.ControlLimitValue = 24
primarylowercontrollimit.ControlLimitText = "LCL"

'upper control limit primary chart
Dim primaryuppercontrollimit As SPCControlLimitRecord = _
  ChartData.GetControlLimitRecord(SPCControlChartData.SPC_PRIMARY_UPPER_CONTROL_LIMIT)
primaryuppercontrollimit.ControlLimitValue = 36
primaryuppercontrollimit.ControlLimitText = "UCL"

' Set control limits for secondary chart
'target control limit secondary chart
Dim secondarytarget As SPCControlLimitRecord = _
  ChartData.GetControlLimitRecord(SPCControlChartData.SPC_SECONDARY_CONTROL_TARGET)
secondarytarget.ControlLimitValue = 10
secondarytarget.ControlLimitText = "RBAR"

'lower control limit secondary chart
Dim secondarylowercontrollimit As SPCControlLimitRecord = _
ChartData.GetControlLimitRecord(SPCControlChartData.SPC_SECONDARY_LOWER_CONTROL_LIMIT)
secondarylowercontrollimit.ControlLimitValue = 0
secondarylowercontrollimit.ControlLimitText = "LCL"

'upper control limit secondary chart
Dim secondaryuppercontrollimit As SPCControlLimitRecord = _
ChartData.GetControlLimitRecord(SPCControlChartData.SPC_SECONDARY_UPPER_CONTROL_LIMIT)
secondaryuppercontrollimit.ControlLimitValue = 22
secondaryuppercontrollimit.ControlLimitText = "UCL"
```

We also added a method (Add3SigmaControlLimits) which will generate multiple control limits, for +-1, 2, and 3- sigma levels, based on an initial specification of the target value, and the +-3 sigma control limits. This is most useful if you want to generate +-1, 2 and 3-sigma control limits in order to fill in between them with a zone fill color. See the TimeVariableControlCharts.MultiLimitXBarRChart example. If you call the

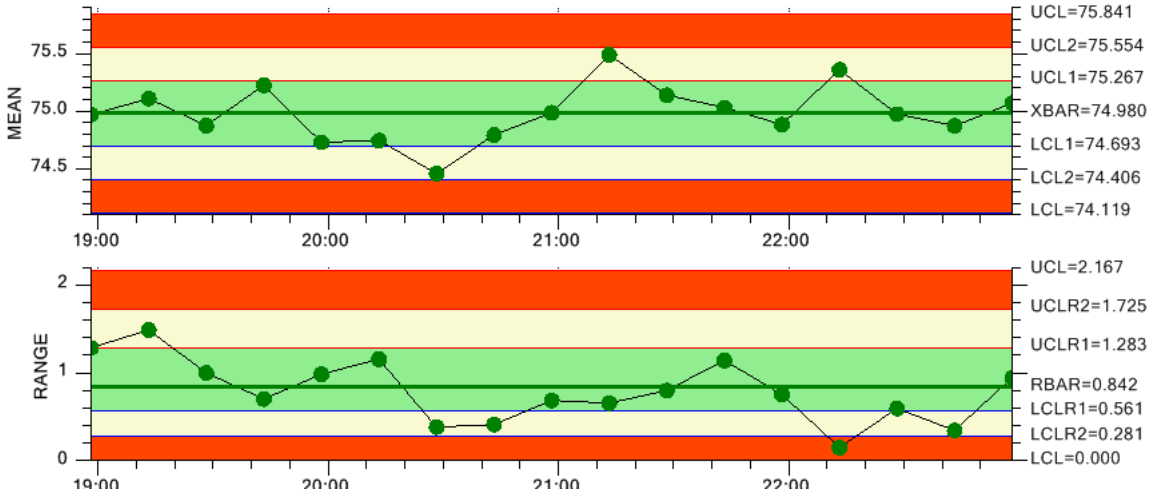
AutoCalculateControlLimits method, the initial +-1,2 and 3-sigma control limit values will be altered to the new, calculated values, but the control limit lines remain, with their new values. Since you do not normally want to be generating alarm messages for excursions into the +-1 and 2-sigma limit areas, the Add3SigmaControl limits has the option of disabling alarm notification in the case of +-1 and +-2 alarm conditions.

[C#]

```
double target = 75, lowlim = 74, highlim = 76;
bool limitcheck = false;
this.PrimaryChart.Add3SigmaControlLimits(target, lowlim, highlim, limitcheck);
this.PrimaryChart.ControlLimitLineFillMode = true;

target = 1; lowlim = 0; highlim = 2;
this.SecondaryChart.Add3SigmaControlLimits(target, lowlim, highlim, limitcheck);
this.SecondaryChart.ControlLimitLineFillMode = true;
```

[VB]

```
Dim target As Double = 75, lowlim As Double = 74, highlim As Double = 76
Dim limitcheck As Boolean = False
Me.PrimaryChart.Add3SigmaControlLimits(target, lowlim, highlim, limitcheck)
Me.PrimaryChart.ControlLimitLineFillMode = True

target = 1
lowlim = 0
highlim = 2
Me.SecondaryChart.Add3SigmaControlLimits(target, lowlim, highlim, limitcheck)
Me.SecondaryChart.ControlLimitLineFillMode = True
```



Control Limit Fill Option used with +-1, 2 and 3-sigma control limits

The second way to set the control limits is to call the **AutoCalculateControlLimits** method. You must have already added a collection of sampled data values to the charts **ChartData** SPC data object before you can call this method, since the method uses the internal **ChartData** object to provide the historical values needed in the calculation.

[C#]

```
// Must have data loaded before any of the Auto.. methods are called
SimulateData();

// Calculate the SPC control limits for both graphs of the current SPC
this.AutoCalculateControlLimits();
```

[VB]
```
' Must have data loaded before any of the Auto.. methods are called
SimulateData()

' Calculate the SPC control limits for both graphs of the current SPC
Me.AutoCalculateControlLimits()
```

You can add data to the **ChartData** object, auto-calculate the control limits to establish the SPC control limits, and continue to add new data values. Alternatively, you can set the SPC control limits explicitly, as the result of previous runs, using the previously described **ChartData.SetControlLimitValues** method, add new sampled data values to the **ChartData** object, and after a certain number of updates call the **AutoCalculateControlLimits** method to establish new control limits.

[C#]
```
updateCount++;
this.ChartData.AddNewSampleRecord(timestamp, samples);
if (updateCount > 50) // After 50 sample groups and calculate limits on the fly
{
// Calculate the SPC control limits for the X-Bar part of the current SPC chart
    this.AutoCalculateControlLimits();
    // Scale the y-axis of the X-Bar chart to display all data and control limits
    this.AutoScalePrimaryChartYRange();
    // Scale the y-axis of the Range chart to display all data and control limits
    this.AutoScaleSecondaryChartYRange();
}
```

[VB]
```
updateCount += 1
Me.ChartData.AddNewSampleRecord(timestamp, samples)
If updateCount > 50 Then ' After 50 sample groups and calculate limits on the fly
   ' Calculate the SPC control limits for the X-Bar part of the current SPC chart
   Me.AutoCalculateControlLimits()
   ' Scale the y-axis of the X-Bar chart to display all data and control limits
   Me.AutoScalePrimaryChartYRange()
   ' Scale the y-axis of the Range chart to display all data and control limits
   Me.AutoScaleSecondaryChartYRange()
End If
```

The **AutoCalculateControlLimits** method calculates the control limits for both the primary and secondary charts. If you want to auto-calculate the control limits for just one of the charts, call the **AutoCalculatePrimaryControlLimits** or **AutoCalculateSecondaryControlLimits** method.

Need to exclude records from the control limit calculation? Call the **ChartData.ExcludeRecordFromControlLimitCalculations** method, passing in true to exclude the record.

[C#]
```
for (int i=0; i < 10; i++)
      this.ChartData.ExcludeRecordFromControlLimitCalculations(i,true);
```

[VB]
```
Dim i As Integer
For i = 0 To 9
```

```
   Me.ChartData.ExcludeRecordFromControlLimitCalculations(i, True)
Next i
```

Formulas Used in Calculating Control Limits for Variable Control Charts

The SPC control limit formulas used by **AutoCalculateControlLimits** in the software derive from the following sources:

X-Bar R, X-Bar Sigma, EWMA, MA and CuSum - "Introduction to Statistical Quality Control" by Douglas C. Montgomery, John Wiley and Sons, Inc. 2001.

Median-Range, Individual-Range - "SPC Simplified – Practical Steps to Quality" by Robert T. Amsden, Productivity Inc., 1998.

SPC Control Chart Nomenclature

UCL = Upper Control Limit

LCL = Lower Control Limit

Center line = The target value for the process

$\bar{\bar{X}}$ = X double-bar - Mean of sample subgroup means (also called the grand average)

$\bar{R}$ = R-bar – Mean of sample subgroup ranges

$\tilde{R}$ = R-Median – Median of sample subgroup ranges

S = Sigma – sample standard deviation

$\bar{S}$ = Sigma-bar – Average of sample subgroup sigma's

M = sample Median

$\tilde{M}$ = Median of sample subgroup medians

X-Bar R Chart – Also known as the Mean (or Average) and Range Chart

Control Limits for the X-Bar Chart

$$UCL = \bar{\bar{X}} + A_2 * \bar{R}$$

$$\text{Center line} = \bar{\bar{X}}$$

$$\text{LCL} = \bar{\bar{X}} - A_2 * \bar{R}$$

Control Limits for the R-Chart

$$\text{UCL} = \bar{R} + D_4 * \bar{R}$$

$$\text{Center line} = \bar{R}$$

$$\text{LCL} = \bar{R} - D_3 * \bar{R}$$

Where the constants A_2, D_3 and D_4 are tabulated in every SPC textbook for various sample sizes.

X-Bar Sigma – Also known as the X-Bar S Chart

Control Limits for the X-Bar Chart

$$\text{UCL} = \bar{\bar{X}} + A_3 * \bar{S}$$

$$\text{Center line} = \bar{\bar{X}}$$

$$\text{LCL} = \bar{\bar{X}} - A_3 * \bar{S}$$

Control Limits for the Sigma-Chart

$$\text{UCL} = \bar{B}_4 * \bar{S}$$

$$\text{Center line} = \bar{S}$$

$$\text{LCL} = \bar{B}_3 * \bar{S}$$

Where the constants A_3, B_3 and B_4 are tabulated in every SPC textbook for various sample sizes.

Median Range – Also known as the Median and Range Chart

Control Limits for the Median Chart

$$UCL = \tilde{M} + A_2 * \tilde{R}$$

$$\text{Center line} = \tilde{M}$$

$$LCL = \tilde{M} - A_2 * \tilde{R}$$

Control Limits for the R-Chart

$$UCL = \tilde{R} + D_4 * \tilde{R}$$

$$\text{Center line} = \tilde{R}$$

$$LCL = \tilde{R} - D_3 * \tilde{R}$$

The constants A_2, D_3 and D_4 for median-range charts are different than those for mean-range charts. A brief tabulation of the median-range chart specific values appears below

Size	**A2**	**D3**	**D4**
2	2.22	0.0	3.87
3	1.26	0.0	2.75
4	0.83	0.0	2.38
5	0.71	0.0	2.18

Individual Range Chart – Also known as the X-R Chart

Control Limits for the X-Bar Chart

$$UCL = \bar{\bar{X}} + E_2 * \bar{R}$$

$$\text{Center line} = \bar{\bar{X}}$$

$$LCL = \bar{\bar{X}} - E_2 * \bar{R}$$

Control Limits for the R-Chart

UCL = $\bar{R} + D_4 * \bar{R}$

Center line = $\bar{R}$

LCL = 0

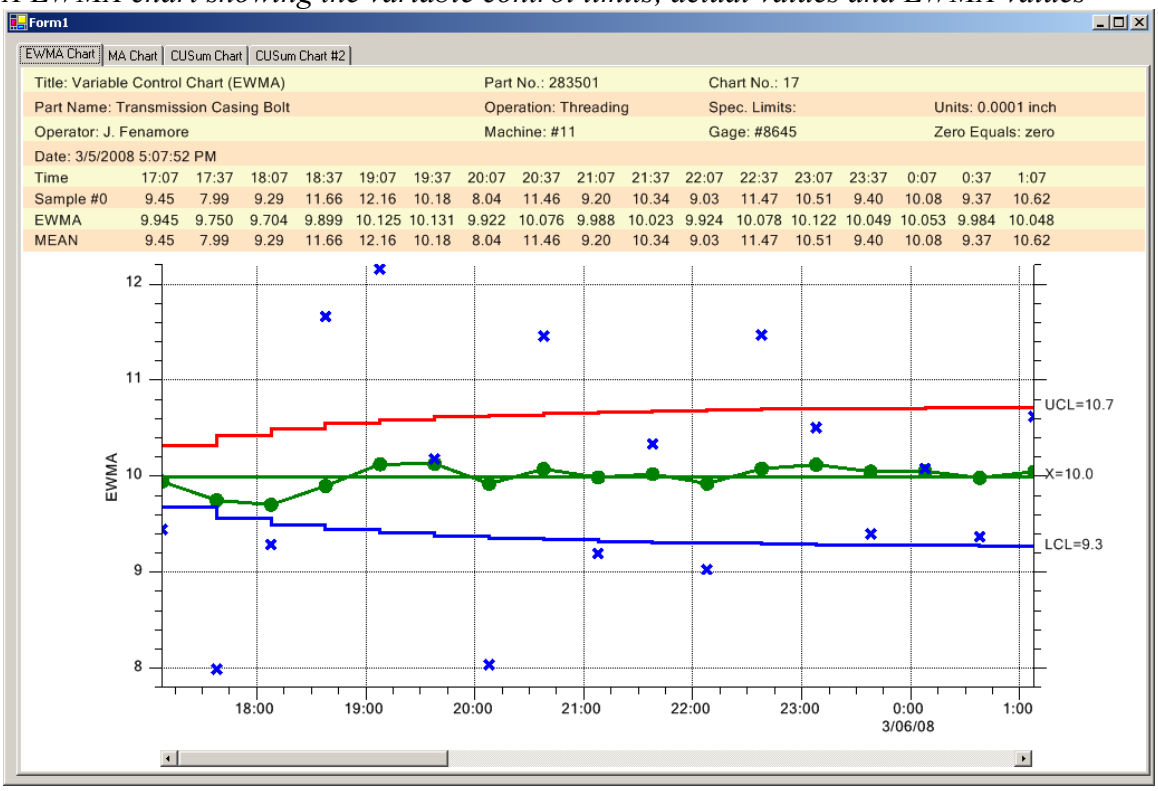
$\bar{R}$ in this case is the average of the moving ranges.

$\bar{X}$ in this case is the mean of the samples

Where the constants E_2 and D_4 are tabulated in every SPC textbook for various sample sizes.

EWMA Chart – Exponentially Weighted Moving Average

A EWMA chart showing the variable control limits, actual values and EWMA values



The current value (z) for an EWMA chart is calculated as an exponentially weighted moving average of all previous samples.

$$z_i = \lambda x_i + (1 - \lambda) z_{i-1}$$

where x_i is the sample value for time interval i, the smoothing value λ has the permissible range of $0 < \lambda \leq 1$ and the starting value (required with the first sample at i = 0) is the process target value, μ_0.

Control Limits for the EWMA Chart

$$UCL = \mu_0 + L * \sigma Sqrt(((\lambda/(2-\lambda)) * (1- (1-\lambda)^{2i}))$$

$$\text{Center line} = \mu_0$$

$$LCL = \mu_0 - L * \sigma Sqrt(((\lambda/(2-\lambda)) * (1- (1-\lambda)^{2i}))$$

F7 $_0$ is the process mean

Shift is the process standard deviation, also known as sigma

Caps Lock is the user specified smoothing value. A typical value for Caps Lock is 0.05, 0.1 or 0.2

L is the width of the control limits. The typical value for L is in the range of 2.7 to 3.0 (corresponding to the usual three-sigma control limits).

The software does not calculate optimal Caps Lock and L values; that is up to you, the programmer to supply, based on your experience with EWMA charts.

Note that the term (1- (1- λ)^{2i}) approaches unity as i increases. The implies that the control limits of an EWMA chart will reach approximate steady state values defined by:

$$UCL = F7_0 + L * Shift Sqrt(Caps Lock/(2- Caps Lock))$$

$$LCL = F7_0 - L * Shift Sqrt(Caps Lock/(2- Caps Lock))$$

It is best if you use the exact equations that take into account the sample period, so that an out of control process can be detected using the tighter control limits that are calculated for small i.

If the EWMA chart is used with subgroup sample sizes greater than 1, the value of x_i is replace by the mean of the corresponding sample subgroup, and the value of Shift is replaced by the value Shift (8) sqrt(n), where in is the sample subgroup size.

You specify Caps Lock and L immediately after the initialization call **InitSPCTimeVaraibleControlChart** (for a time-based variable control chart), or **InitSPCBatchVariableControlChart** (for a batch-based variable control chart). See the examples MiscTimeBasedControlCharts.EWMAChart, and MiscBatchBasedControlCharts.EWMAChart. Specify L using the **DefaultControlLimitSigma** property, and Caps Lock using the **EWMA_Lambda** property. You can optionally set the EWMA starting value (**EWMA**_StartingValue), normally set to the process mean value, and whether or not to use the steady-state EWMA control limits (**UseSSLimits**).

Extracted from the MiscTimeBasedControlCharts.EWMAChart example.

[C#]

```
//  SPC variable control chart type
int charttype = SPCControlChartData.EWMA_CHART;
.
.
.
// Initialize the SPCTimeVariableControlChart
this.InitSPCTimeVariableControlChart(charttype,
    numsamplespersubgroup, numdatapointsinview, sampleincrement);
```

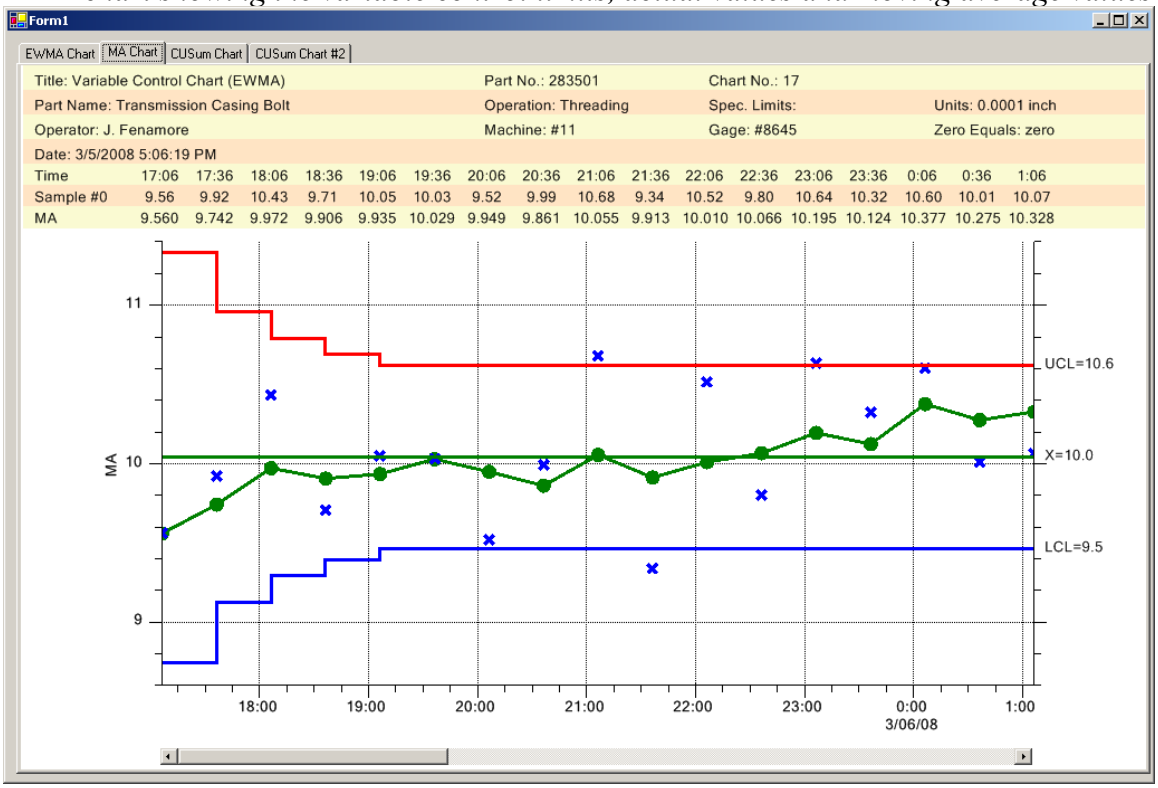
```
this.ChartData.EWMA_StartingValue = 10; // Set to estimate of mean of process variable.
this.ChartData.EWMA_Lambda = 0.1;
this.DefaultControlLimitSigma = 2.7; // Specifies L value
this.ChartData.EWMA_UseSSLimits = false;
```

[VB]

```
'  SPC variable control chart type
Private charttype As Integer = SPCControlChartData.EWMA_CHART
.
.
.
' Initialize the SPCTimeVariableControlChart
Me.InitSPCTimeVariableControlChart(charttype, numsamplespersubgroup, _
   numdatapointsinview, timeincrementminutes)
Me.ChartData.EWMA_StartingValue = 10 ' Set to estimate of mean of process variable.
Me.ChartData.EWMA_Lambda = 0.1
Me.DefaultControlLimitSigma = 2.7
Me.ChartData.EWMA_UseSSLimits = False
```

MA Chart – Moving Average

A MA chart showing the variable control limits, actual values and moving average values



The current value (z) for a MA chart is calculated as a weighted moving average of the N most recent samples.

$$z_i = (x_i + x_{i-1} + x_{i-2} + \ldots \; x_{i-N+1})/N$$

where x_i is the sample value for time interval i, and N is the length of the moving average.

Control Limits for the MA Chart

UCL = F7 + 3 * Shift / sqrt(N)

Center line = F7

LCL = F7 - 3 * Shift / sqrt(N)

F7 is the process mean

Shift is the process standard deviation, also known as sigma

N is the length of the moving average used to calculate the current chart value

Control Limits for the MR part of the MAMR (Moving Average/Moving Range Chart

Control Limits for the R-Chart

UCL = $\bar{R}$ + D_4 * $\bar{R}$

Center line = $\bar{R}$

LCL = 0

$\bar{R}$ in this case is the average of the moving ranges.

Where the constant D_4 is tabulated in every SPC textbook for various sample sizes.

Control Limits for the MS part of the MAMS (Moving Average/Moving Sigma Chart

UCL = $\bar{B}_4$ * $\bar{S}$

Center line = $\bar{S}$

_ _

$$LCL = B_3 * \bar{S}$$

$\bar{S}$ in this case is the average of the moving sigmas.

Where the constant B_4 is tabulated in every SPC textbook for various sample sizes.
The software does not calculate an optimal N value; that is up to you, the programmer to supply, based on your past experience with MA charts.

For the values of z_i where i < N-1, the weighted average and control limits are calculated using the actual number of samples used in the average, rather than N. This results in expanded values for the control limits for small i < N-1.

You specify N, the length of the moving average, immediately after the initialization call **InitSPCTimeVaraibleControlChart** (for a time-based variable control chart), or **InitSPCBatchVariableControlChart** (for a batch-based variable control chart). Set the process mean and process sigma used in the control limit calculations using the **ProcessMean** and **ProcessSigma** properties.
See the examples MiscTimeBasedControlCharts.MAChart, and MiscBatchBasedControlCharts.MAChart. Specify N using the **MA_w** property.

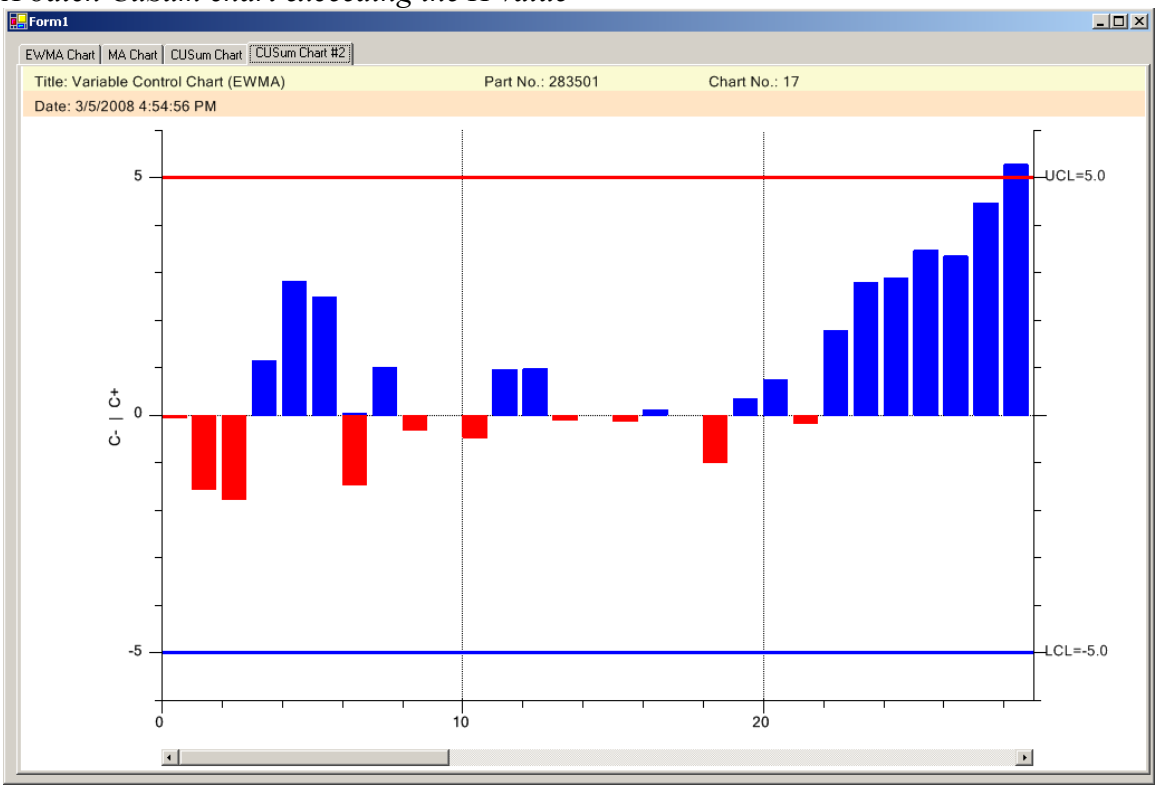
Extracted from the MiscTimeBasedControlCharts.MAChart example.

[C#]
```
//  SPC variable control chart type
int charttype = SPCControlChartData.MA_CHART;
.
.
.
// Initialize the SPCTimeVariableControlChart
this.InitSPCTimeVariableControlChart(charttype,
numsamplespersubgroup, numdatapointsinview, sampleincrement);
// Number of time periods in moving average
this.ChartData.MA_w = 9;
```

[VB]
```
'  SPC variable control chart type
Private charttype As Integer = SPCControlChartData.MA_CHART
.
.
.
' Initialize the SPCTimeVariableControlChart
Me.InitSPCTimeVariableControlChart(charttype, numsamplespersubgroup, _
   numdatapointsinview, timeincrementminutes)
' Number of time periods in moving average
Me.ChartData.MA_w = 7
Me.ChartData.ProcessMean = 10.0
Me.ChartData.ProcessSigma = 1.0
```

CuSum Chart – Tabular, one-sided, upper and lower cumulative sum

A batch CuSum chart exceeding the H value



The tabular cusum works by accumulating deviations from the process mean, $F7_0$. Positive deviations are accumulated in the one sided upper cusum statistic, C^+, and negative deviations are accumulated in the one sided lower cusum statistic, C^-. The statistics are calculated using the following equations:

$$C^+_i = \max[0, x_i - (F7_0 + K) + C^+_{i-1}]$$

$$C^-_i = \max[0, (F7_0 - K) - x_i + C^+_{i-1}]$$

where the starting values are $C^+_0 = C^-_0 = 0$

$F7_0$ is the process mean

K is the reference (or slack value) that is usually selected to be one-half the magnitude of the difference between the target value, $F7_0$, and the out of control process mean value, $F7_1$, that you are trying to detect.

$K = ABS(F7_1 - F7_0)/2$

The control limits used by the chart are +-H. If the value of either C^+ or C^- exceed +- H, the process is considered out of control.

The software does not calculate an optimal H or K value; that is up to you, the programmer to supply, based on your past experience with CuSum charts. Typically H is set equal to 5 times the process standard deviation, Shift. Typically K is selected to be one-half the magnitude of the difference between the target value, F7 0, and the out of control process mean value, F7 1, that you are trying to detect. You specify H and K in the initialization call **InitSPCTimeCusumControlChart** (for a time-based variable control chart), or **InitSPCBatchCusumControlChart** (for a batch-based variable control chart). See the examples MiscTimeBasedControlCharts.CUSumChart, MiscTimeBasedControlCharts.CUSumChart2, MiscBatchBasedControlCharts.CUSumChart, and MiscBatchBasedControlCharts.CUSumChart2.

Extracted from MiscTimeBasedControlCharts.CUSumChart

[C#]

```
int charttype = SPCControlChartData.TABCUSUM_CHART;
double processMean = 10;
double kValue = 0.5;
double hValue = 5;
.
.
// Initialize the SPCTimeVariableControlChart
this.InitSPCTimeCusumControlChart(charttype,
    numsamplespersubgroup, numdatapointsinview, sampleincrement,
    processMean, kValue, hValue);
```

[VB]

```
Private charttype As Integer = SPCControlChartData.TABCUSUM_CHART
Private processMean As Double = 10
Private kValue As Double = 0.5
Private hValue As Double = 5
.
.
' Initialize the SPCTimeVariableControlChart
Me.InitSPCTimeCusumControlChart(charttype, numsamplespersubgroup, _
    numdatapointsinview, timeincrementminutes, processMean, kValue, hValue)
```

Or, you can call the **InitSPCTimeCusumControlChart** method and specify H and K using immediately afterwards using simple property calls.

Extracted from MiscTimeBasedControlCharts.CUSumChart2

[C#]

```
int charttype = SPCControlChartData.TABCUSUM_CHART;
double processMean = 10;
double kValue = 0.5;
double hValue = 5;
.
.
.
// Initialize the SPCTimeVariableControlChart
this.InitSPCTimeVariableControlChart(charttype,
    numsamplespersubgroup, numdatapointsinview, sampleincrement);
this.ChartData.CusumHValue = hValue;
this.ChartData.CusumKValue = kValue;
```

```
this.ChartData.ProcessMean = processMean;
```

[VB]

```
Private charttype As Integer = SPCControlChartData.TABCUSUM_CHART
Private processMean As Double = 10
Private kValue As Double = 0.5
Private hValue As Double = 5
.
.
.
' Initialize the SPCTimeVariableControlChart
Me.InitSPCTimeVariableControlChart(charttype, numsamplespersubgroup, _
    numdatapointsinview, timeincrementminutes)
Me.ChartData.CusumHValue = hValue
Me.ChartData.CusumKValue = kValue
Me.ChartData.ProcessMean = processMean
```

Variable SPC Control Limits

There can be situations where SPC control limits change in a chart. If the control limits change, you need to set the following **ControlLineMode** property to SPCChartObjects.CONTROL_LINE_VARIABLE, as in the example below. The default value is SPCChartObjects.CONTROL_LINE_FIXED.

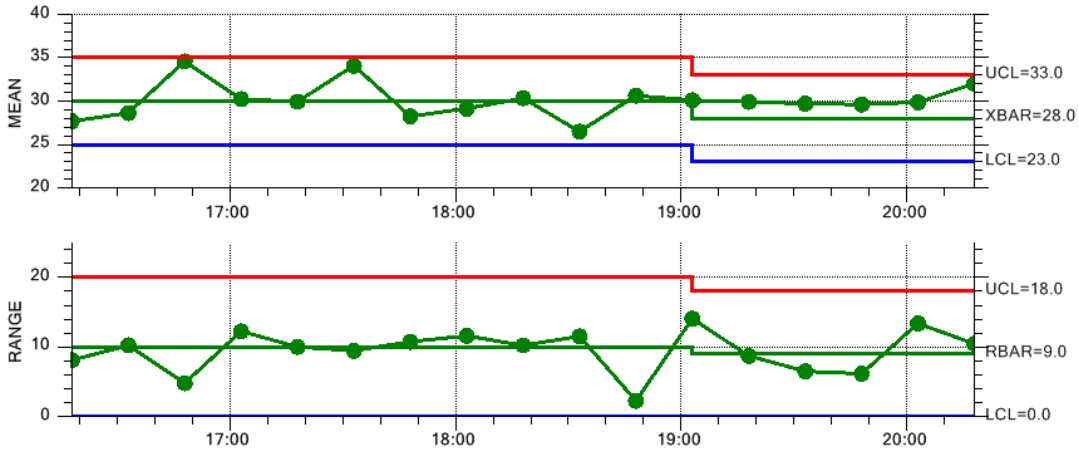
[C#]

```
this.PrimaryChart.ControlLineMode = SPCChartObjects.CONTROL_LINE_VARIABLE;
this.SecondaryChart.ControlLineMode = SPCChartObjects.CONTROL_LINE_VARIABLE;
```

[VB]

```
Me.PrimaryChart.ControlLineMode = SPCChartObjects.CONTROL_LINE_VARIABLE
Me.SecondaryChart.ControlLineMode = SPCChartObjects.CONTROL_LINE_VARIABLE
```

In the SPCChartObjects.CONTROL_LINE_FIXED case, the current SPC control limit plots as a horizontal straight line for the entire width of the chart, regardless if the control limit changes, either explicitly, or using the **AutoCalculateControlLimits** method. If the **ControlLineMode** property is SPCChartObjects.CONTROL_LINE_VARIABLE, the SPC limit value plots at the value it had when the sample subgroup values updated. If you change a control limit value, the control limit line will no longer be a straight horizontal line, instead it will be jagged, or stepped, depending on the changes made.



There are three ways to enter new SPC limit values. See the example program TimeVaraibleControlCharts.VariableControlLimits for an example of all three methods. First, you can use the method **ChartData.SetControlLimitValues** method.

[C#]

```
double [] initialControlLimits = {30, 25, 35, 10, 0, 20};
double [] changeControlLimits = {28, 23, 33, 9, 0, 18};
.
.
this.PrimaryChart.ControlLineMode = SPCChartObjects.CONTROL_LINE_VARIABLE;
.
.
// Change limits at sample subgroup 10
if (i== 10)
{
    this.ChartData.SetControlLimitValues(changeControlLimits);
}
this.ChartData.AddNewSampleRecord(timestamp, samples, notesstring);
```

[VB]

```
Dim initialControlLimits() As Double = {30, 25, 35, 10, 0, 20}
Dim changeControlLimits() As Double = {28, 23, 33, 9, 0, 18}
.
.
Me.PrimaryChart.ControlLineMode = SPCChartObjects.CONTROL_LINE_VARIABLE
.
.
' Change limits at sample subgroup 10
If i = 10 Then
   Me.ChartData.SetControlLimitValues(changeControlLimits)
End If
Me.ChartData.AddNewSampleRecord(timestamp, samples, notesstring)
```

Second, you can use the **AutoCalculateControlLimits** method. You must have already added a collection of sampled data values to the charts **ChartData** SPC data object before you can call this method, since the method uses the internal **ChartData** object to provide the historical values needed in the calculation.

[C#]

```
.
.
this.PrimaryChart.ControlLineMode = SPCChartObjects.CONTROL_LINE_VARIABLE;
.
.

//  Variable Control Limits re-calculated every update after 10 using
//  AutoCalculateControlLimits
    if (i > 10)
        this.AutoCalculateControlLimits();
    this.ChartData.AddNewSampleRecord(timestamp, samples, notesstring);
```

[VB]

```
.
.
Me.PrimaryChart.ControlLineMode = SPCChartObjects.CONTROL_LINE_VARIABLE
.
.

'  Variable Control Limits re-calculated every update after 10 using
'  AutoCalculateControlLimits
If i > 10 Then
  Me.AutoCalculateControlLimits()
End If
Me.ChartData.AddNewSampleRecord(timestamp, samples, notesstring)
```

Last, you can enter the SPC control limits with every new sample subgroup record, using one of the methods that include a control limits array parameter.

[C#]

```
double [] initialControlLimits = {30, 25, 35, 10, 0, 20};
double [] changeControlLimits = {28, 23, 33, 9, 0, 18};
DoubleArray variableControlLimits;
.
.
this.PrimaryChart.ControlLineMode = SPCChartObjects.CONTROL_LINE_VARIABLE;
.
.
//      Variable Control Limits updated using AddNewSampleRecord
    if (i== 10) // need to convert changeControlLimits to a DoubleArray
        variableControlLimits = new DoubleArray(changeControlLimits);
    this.ChartData.AddNewSampleRecord(timestamp, samples,
        variableControlLimits, notesstring);
```

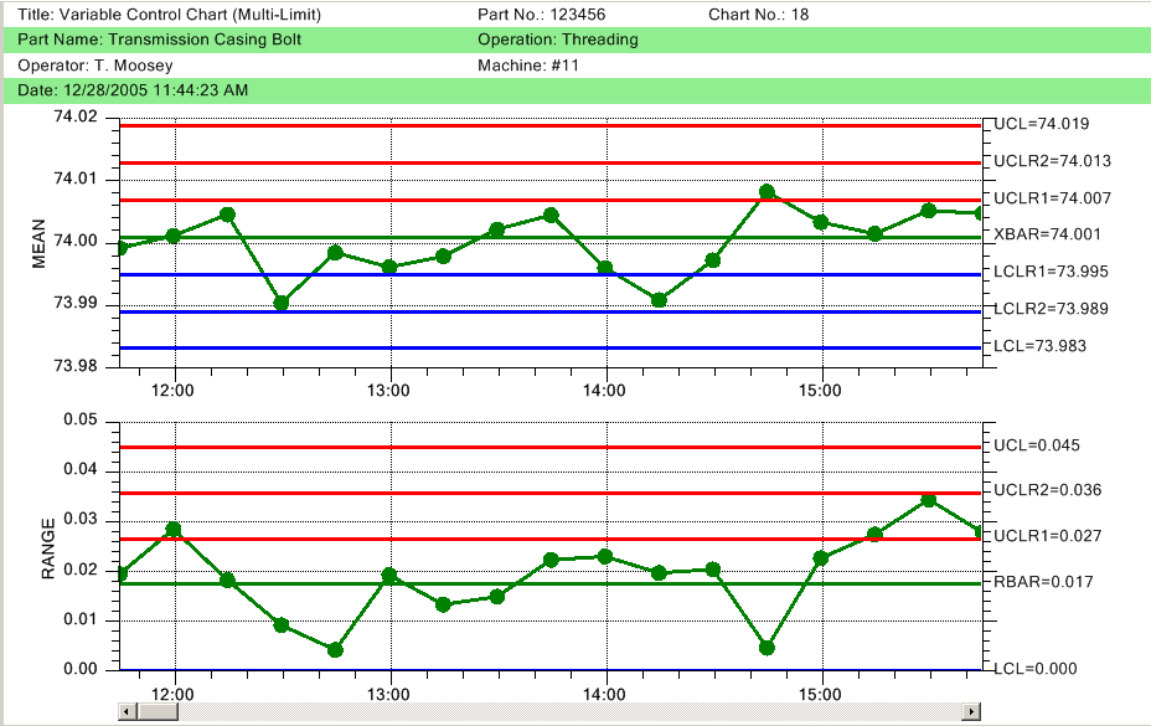
[VB]

```
Dim initialControlLimits() As Double = {30, 25, 35, 10, 0, 20}
Dim changeControlLimits() As Double = {28, 23, 33, 9, 0, 18}
Dim variableControlLimits As DoubleArray
.
.
Me.PrimaryChart.ControlLineMode = SPCChartObjects.CONTROL_LINE_VARIABLE
.
.
'  Variable Control Limits updated using AddNewSampleRecord
 If i = 10 Then ' need to convert changeControlLimits to a DoubleArray
   variableControlLimits = New DoubleArray(changeControlLimits)
 End If
 Me.ChartData.AddNewSampleRecord(timestamp, samples, variableControlLimits, _
        notesstring)
```

Multiple SPC Control Limits

The normal SPC control limit displays at the 3-sigma level, both high and low. A common standard is that if the process variable under observation falls outside of the +-3-sigma limits the process is out of control. The default setup of our variable control charts have a high limit at the +3-sigma level, a low limit at the -3-sigma level, and a target value. There are situations where the quality engineer also wants to display control limits at the 1-sigma and 2-sigma level. The operator might receive some sort of preliminary warning if the process variable exceeds a 2-sigma limit.

You are able to add additional control limit lines to a variable control chart, as in the example program TimeVariableControlCharts.MultiLimitXBarRChart.



We also added a method (Add3SigmaControlLimits) which will generate multiple control limits, for +-1, 2, and 3- sigma levels, based on an initial specification of the target value, and the +-3 sigma control limits. This is most useful if you want to generate +-1, 2 and 3-sigma control limits in order to fill in between them with a zone fill color. See the TimeVariableControlCharts.MultiLimitXBarRChart example. If you call the AutoCalculateControlLimits method, the initial +-1,2 and 3-sigma control limit values will be altered to the new, calculated values, but the control limit lines remain, with their new values. Since you do not normally want to be generating alarm messages for excursions into the +-1 and

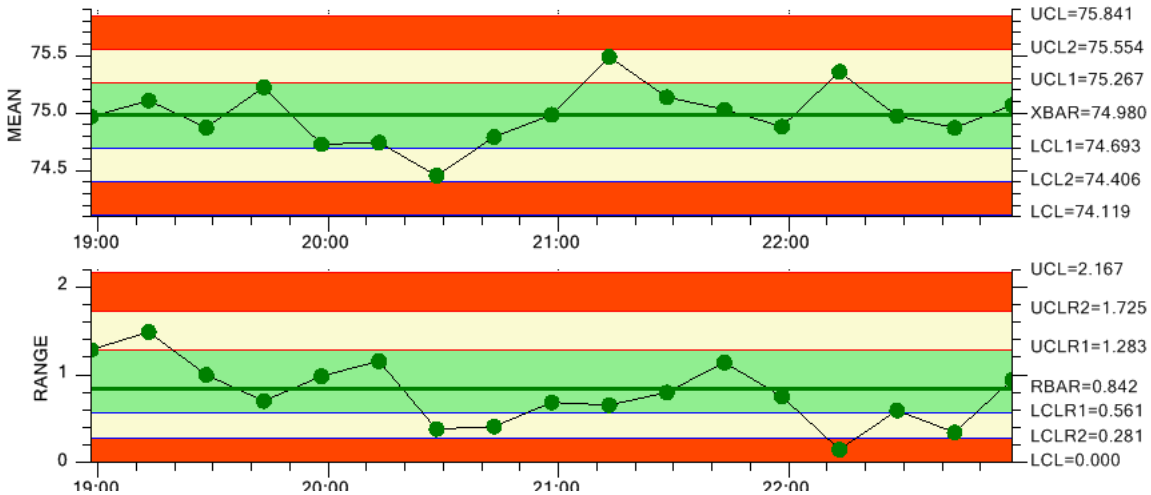
2-sigma limit areas, the Add3SigmaControl limits has the option of disabling alarm notification in the case of +-1 and +-2 alarm conditions.

[C#]

```
double target = 75, lowlim = 74, highlim = 76;
bool limitcheck = false;
this.PrimaryChart.Add3SigmaControlLimits(target, lowlim, highlim, limitcheck);
this.PrimaryChart.ControlLimitLineFillMode = true;

target = 1; lowlim = 0; highlim = 2;
this.SecondaryChart.Add3SigmaControlLimits(target, lowlim, highlim, limitcheck);
this.SecondaryChart.ControlLimitLineFillMode = true;
```

[VB]

```
Dim target As Double = 75, lowlim As Double = 74, highlim As Double = 76
Dim limitcheck As Boolean = False
Me.PrimaryChart.Add3SigmaControlLimits(target, lowlim, highlim, limitcheck)
Me.PrimaryChart.ControlLimitLineFillMode = True

target = 1
lowlim = 0
highlim = 2
Me.SecondaryChart.Add3SigmaControlLimits(target, lowlim, highlim, limitcheck)
Me.SecondaryChart.ControlLimitLineFillMode = True
```



Control Limit Fill Option used with +-1, 2 and 3-sigma control limits

You can also add additional control limits one at a time. By default you get the +-3-sigma control limits. So additional control limits should be considered +-2-sigma and +-1-sigma control limits. Do not confuse control limits with specification limits, which must be added using the **AddSpecLimit** method. There are two steps to adding additional control limits: creating a SPCControlLimitRecord object for the new control limit, and adding the control limit to the chart using the charts AddAdditionalControlLimit method. It is critical that you add them in a specific order, that order being:

Primary Chart	SPC_LOWER_CONTROL_LIMIT_2	(2-sigma lower limit)
Primary Chart	SPC_UPPER_CONTROL_LIMIT_2	(2-sigma lower limit)
Primary Chart	SPC_LOWER_CONTROL_LIMIT_1	(1-sigma lower limit)

Primary Chart	SPC_UPPER_CONTROL_LIMIT_1	(1-sigma lower limit)
Secondary Chart	SPC_LOWER_CONTROL_LIMIT_2	(2-sigma lower limit)
Secondary Chart	SPC_UPPER_CONTROL_LIMIT_2	(2-sigma lower limit)
Secondary Chart	SPC_LOWER_CONTROL_LIMIT_1	(1-sigma lower limit)
Secondary Chart	SPC_UPPER_CONTROL_LIMIT_1	(1-sigma lower limit)

[C#]

```
double sigma2 = 2.0;
double sigma1 = 1.0;


this.PrimaryChart.GetControlLimitData(SPCChartObjects.SPC_LOWER_CONTROL_LIMIT).LimitValue
= 74;

this.PrimaryChart.GetControlLimitData(SPCChartObjects.SPC_UPPER_CONTROL_LIMIT).LimitValue
= 76;

this.PrimaryChart.GetControlLimitData(SPCChartObjects.SPC_CONTROL_TARGET).LimitValue = 75;

// Create multiple limits
// For PrimaryChart
SPCControlLimitRecord lcl2 = new SPCControlLimitRecord(this.ChartData,
SPCControlLimitRecord.SPC_LOWERTHAN_LIMIT, 74.33,"LCL2", "LCL2");
SPCControlLimitRecord ucl2 = new SPCControlLimitRecord(this.ChartData,
SPCControlLimitRecord.SPC_GREATERTHAN_LIMIT, 75.66,"UCL2", "UCL2");

this.PrimaryChart.AddAdditionalControlLimit(lcl2,
SPCChartObjects.SPC_LOWER_CONTROL_LIMIT_2, sigma2);
this.PrimaryChart.AddAdditionalControlLimit(ucl2,
SPCChartObjects.SPC_UPPER_CONTROL_LIMIT_2, sigma2);

SPCControlLimitRecord lcl3 = new SPCControlLimitRecord(this.ChartData,
SPCControlLimitRecord.SPC_LOWERTHAN_LIMIT, 74.66,"LCL1", "LCL1");
SPCControlLimitRecord ucl3 = new SPCControlLimitRecord(this.ChartData,
SPCControlLimitRecord.SPC_GREATERTHAN_LIMIT, 75.33,"UCL1", "UCL1");

this.PrimaryChart.AddAdditionalControlLimit(lcl3,
SPCChartObjects.SPC_LOWER_CONTROL_LIMIT_1, sigma1);
this.PrimaryChart.AddAdditionalControlLimit(ucl3,
SPCChartObjects.SPC_UPPER_CONTROL_LIMIT_1, sigma1);

           // For Secondary Chart

this.SecondaryChart.GetControlLimitData(SPCChartObjects.SPC_LOWER_CONTROL_LIMIT).LimitVal
ue = 2;

this.SecondaryChart.GetControlLimitData(SPCChartObjects.SPC_UPPER_CONTROL_LIMIT).LimitVal
ue = 0;

this.SecondaryChart.GetControlLimitData(SPCChartObjects.SPC_CONTROL_TARGET).LimitValue =
1;

SPCControlLimitRecord lcl4 = new SPCControlLimitRecord(this.ChartData,
SPCControlLimitRecord.SPC_LOWERTHAN_LIMIT, 0.33,"LCL2", "LCL2");
SPCControlLimitRecord ucl4 = new SPCControlLimitRecord(this.ChartData,
SPCControlLimitRecord.SPC_GREATERTHAN_LIMIT, 1.66,"UCL2", "UCL2");

this.SecondaryChart.AddAdditionalControlLimit(lcl4,
SPCChartObjects.SPC_LOWER_CONTROL_LIMIT_2, sigma2);
this.SecondaryChart.AddAdditionalControlLimit(ucl4,
SPCChartObjects.SPC_UPPER_CONTROL_LIMIT_2, sigma2);

SPCControlLimitRecord lcl5 = new SPCControlLimitRecord(this.ChartData,
SPCControlLimitRecord.SPC_LOWERTHAN_LIMIT, 0.66,"LCL1", "LCL1");
```

```
SPCControlLimitRecord  ucl5 = new SPCControlLimitRecord(this.ChartData,
SPCControlLimitRecord.SPC_GREATERTHAN_LIMIT, 1.33,"UCL1", "UCL1");

this.SecondaryChart.AddAdditionalControlLimit(lcl5,
SPCChartObjects.SPC_LOWER_CONTROL_LIMIT_1, sigma1);
this.SecondaryChart.AddAdditionalControlLimit(ucl5,
SPCChartObjects.SPC_UPPER_CONTROL_LIMIT_1, sigma1);

this.PrimaryChart.ControlLimitLineFillMode = true;

this.SecondaryChart.ControlLimitLineFillMode = true;
```

[VB]

```
Dim sigma2 As Double = 2.0
Dim sigma1 As Double = 1.0
' Create multiple limits
For PrimaryChart

Me.PrimaryChart.GetControlLimitData(SPCChartObjects.SPC_LOWER_CONTROL_LIMIT).LimitValue =
74

Me.PrimaryChart.GetControlLimitData(SPCChartObjects.SPC_UPPER_CONTROL_LIMIT).LimitValue =
76

Me.PrimaryChart.GetControlLimitData(SPCChartObjects.SPC_CONTROL_TARGET).LimitValue = 75

Dim lcl2 As New SPCControlLimitRecord(Me.ChartData, _
   SPCControlLimitRecord.SPC_LOWERTHAN_LIMIT, 74.33, "LCL2", "LCL2") '
Dim ucl2 As New SPCControlLimitRecord(Me.ChartData, _
     SPCControlLimitRecord.SPC_GREATERTHAN_LIMIT, 75.66, "UCL2", "UCL2")

Me.PrimaryChart.AddAdditionalControlLimit(lcl2, _
    SPCChartObjects.SPC_LOWER_CONTROL_LIMIT_2, sigma2)
Me.PrimaryChart.AddAdditionalControlLimit(ucl2, _
    SPCChartObjects.SPC_UPPER_CONTROL_LIMIT_2, sigma2)

Dim lcl3 As New SPCControlLimitRecord(Me.ChartData, _
      SPCControlLimitRecord.SPC_LOWERTHAN_LIMIT, 74.66, "LCL1", "LCL1")
Dim ucl3 As New SPCControlLimitRecord(Me.ChartData, _
      SPCControlLimitRecord.SPC_GREATERTHAN_LIMIT, 75.33, "UCL1", "UCL1")

Me.PrimaryChart.AddAdditionalControlLimit(lcl3, _
      SPCChartObjects.SPC_LOWER_CONTROL_LIMIT_1, sigma1)
Me.PrimaryChart.AddAdditionalControlLimit(ucl3, _
     SPCChartObjects.SPC_UPPER_CONTROL_LIMIT_1, sigma1)

        ' For Secondary Chart

Me.SecondaryChart.GetControlLimitData(SPCChartObjects.SPC_LOWER_CONTROL_LIMIT).LimitValue
= 0

Me.SecondaryChart.GetControlLimitData(SPCChartObjects.SPC_UPPER_CONTROL_LIMIT).LimitValue
= 2

Me.SecondaryChart.GetControlLimitData(SPCChartObjects.SPC_CONTROL_TARGET).LimitValue = 1

Dim lcl4 As SPCControlLimitRecord = New SPCControlLimitRecord(Me.ChartData,
SPCControlLimitRecord.SPC_LOWERTHAN_LIMIT, 0.33, "LCL2", "LCL2")
Dim ucl4 As SPCControlLimitRecord = New SPCControlLimitRecord(Me.ChartData,
SPCControlLimitRecord.SPC_GREATERTHAN_LIMIT, 1.66, "UCL2", "UCL2")

Me.SecondaryChart.AddAdditionalControlLimit(lcl4,
SPCChartObjects.SPC_LOWER_CONTROL_LIMIT_2, sigma2)
Me.SecondaryChart.AddAdditionalControlLimit(ucl4,
SPCChartObjects.SPC_UPPER_CONTROL_LIMIT_2, sigma2)

Dim lcl5 As SPCControlLimitRecord = New SPCControlLimitRecord(Me.ChartData,
SPCControlLimitRecord.SPC_LOWERTHAN_LIMIT, 0.66, "LCL1", "LCL1")
Dim ucl5 As SPCControlLimitRecord = New SPCControlLimitRecord(Me.ChartData,
SPCControlLimitRecord.SPC_GREATERTHAN_LIMIT, 1.33, "UCL1", "UCL1")
```

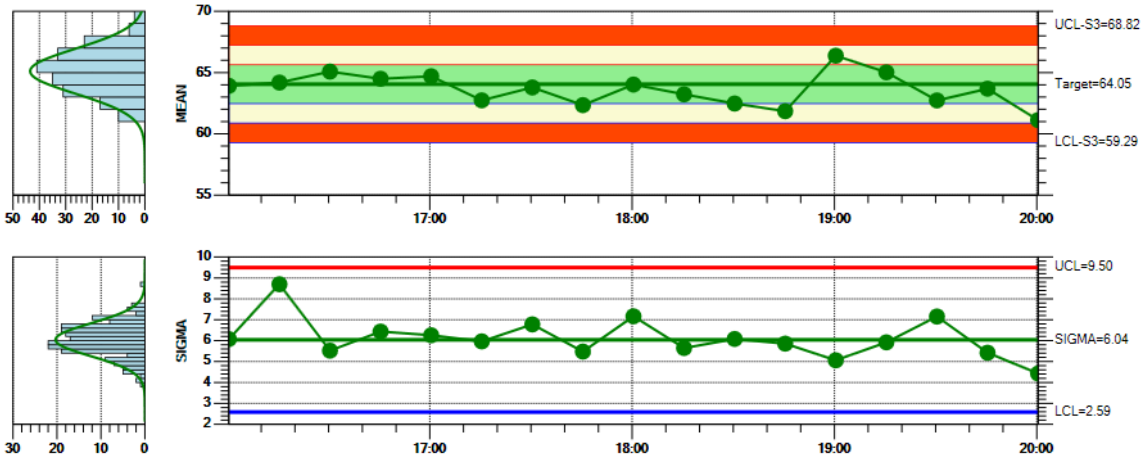
```
Me.SecondaryChart.AddAdditionalControlLimit(lcl5,
SPCChartObjects.SPC_LOWER_CONTROL_LIMIT_1, sigma1)
Me.SecondaryChart.AddAdditionalControlLimit(ucl5,
SPCChartObjects.SPC_UPPER_CONTROL_LIMIT_1, sigma1)

Me.PrimaryChart.ControlLimitLineFillMode = True
Me.SecondaryChart.ControlLimitLineFillMode = True
```

Special Note – When you create a **SPCControlLimitRecord** object, you can specify an actual limit level. If you do not call the charts **AutoCalculateControlLimits** method, the control limit will be displayed at that value. If you do call **AutoCalculateControlLimits** method, the auto-calculated value overrides the initial value (0.0 in the examples above). When you call the charts **AddAdditionalControlLimits** method, you specify the sigma level that is used by the **AutoCalculateControlLimits** to calculate the control limit level.

If you want the control limits displayed as filled areas, set the charts **ControlLimitLineFillMode** property True.

```
[C#]
this.PrimaryChart.ControlLimitLineFillMode = true;
```

This will fill each control limit line from the limit line to the target value of the chart. In order for the fill to work properly, you must set this property after you define all additional control limits. Also, you must add the outer most control limits (SPC_UPPER_CONTROL_LIMIT_3 and SPC_LOWER_CONTROL_LIMIT_3) first, followed by the next outer most limits (SPC_UPPER_CONTROL_LIMIT_2 and SPC_LOWER_CONTROL_LIMIT_2), followed by the inner most control limits (SPC_UPPER_CONTROL_LIMIT_1 and SPC_LOWER_CONTROL_LIMIT_1). This way the fill of the inner limits will partially cover the fill of the outer limits, creating the familiar striped look you want to see.



Western Electric (WE) Runtime Rules

The normal SPC control limit rules display at the 3-sigma level, both high and low. In this case, a simple threshold test determines if a process is in, or out of control. Other, more complex tests rely on more complicated decision-making criteria. The most popular of these are the Western

Electric Rules, also know as the WE Rules, or WE Runtime Rules. These rules utilize historical data for the eight most recent sample intervals and look for a non-random pattern that can signify that the process is out of control, before reaching the normal +-3 sigma limits. A processed is considered out of control if any of the following criteria are met:

*Starting with Revision 3.0, we have added additional, industry standard rules to the software: Nelson, AAIG, Juran, Hughes, Gitlow, Westgard, and Duncan. In addition, you can mix and match rules from the different rule sets, and you can create your own custom rules using our standardize rule templates. See Chapter 8, for more information.

1. **The most recent point plots outside one of the 3-sigma control limits.** If a point lies outside either of these limits, there is only a 0.3% chance that this was caused by the normal process.

2. **Two of the three most recent points plot outside and on the same side as one of the 2-sigma control limits.** The probability that any point will fall outside the warning limit is only 5%. The chances that two out of three points in a row fall outside the warning limit is only about 1%.

3. **Four of the five most recent points plot outside and on the same side as one of the 1-sigma control limits.** In normal processing, 68% of points fall within one sigma of the mean, and 32% fall outside it. The probability that 4 of 5 points fall outside of one sigma is only about 3%.

4. **Eight out of the last eight points plot on the same side of the center line, or target value.** Sometimes you see this as 9 out of 9, or 7 out of 7. There is an equal chance that any given point will fall above or below the mean. The chances that a point falls on the same side of the mean as the one before it is one in two. The odds that the next point will also fall on the same side of the mean is one in four. The probability of getting eight points on the same side of the mean is only around 1%.

These rules apply to both sides of the center line at a time. Therefore, there are eight actual alarm conditions: four for the above center line sigma levels and four for the below center line sigma levels.

There are also additional WE Rules for trending. These are often referred to as WE Supplemental Rules. Don't rely on the rule number, often these are listed in a different order.

5. **Six points in a row increasing or decreasing.** The same logic is used here as for rule 4 above. Sometimes this rule is changed to seven points rising or falling.

6. **Fifteen points in a row within one sigma.** In normal operation, 68% of points will fall within one sigma of the mean. The probability that 15 points in a row will do so, is less than 1%.

7. **Fourteen points in a row alternating direction.** The chances that the second point is always higher than (or always lower than) the preceding point, for all seven pairs is only about 1%.

8. **Eight points in a row outside one sigma.** Since 68% of points lie within one sigma of the mean, the probability that eight points in a row fall outside of the one-sigma line is less than 1%.

While the techniques in the previous section can be used to draw multiple SPC control limit lines on the graph, at the +-1, 2, 3 sigma levels for example, they do not provide for the (x out of y) control criteria used in evaluating the WE rules. The software can be explicitly flagged to evaluate out of control alarm conditions according to the WE Rules, instead of the default +-3 sigma control criteria. It will create alarm lines at the +-1, 2, and 3-sigma control limits and the center line. It will also automatically establish the eight alarm conditions associated with the WE rules. Set the WE rules flag using the PrimaryChart (or SecondaryChart) **UseWERuntimeRules** method. When the variable control charts **AutoCalculatedControlLimits** method is called, the software automatically calculates all of the appropriated control limits, based on the current data. The example below is extracted from the WERulesVariableControlChart.XBarRCharts example program.

If you want to include the WE Trending (Supplemental) rules, in addition to the regular WE Runtime rules, call UseWERuntimeAndSupplementalRules in place of UseWERuntimeRules.

[C#]

```
this.ChartData.AlarmStateEventHandler +=
       new SPCControlLimitAlarmEventDelegate(this.SPCControlLimitAlarm);
// don't generate alarms in initial data simulation
this.ChartData.AlarmStateEventEnable = false;

this.PrimaryChart.UseWERuntimeRules();
//this.PrimaryChart.UseWERuntimeAndSupplementalRules();

// Must have data loaded before any of the Auto.. methods are called
 SimulateData(100, 20);

// Calculate the SPC control limits for both graphs of the current SPC chart (X-Bar R)
this.AutoCalculateControlLimits();

// throw out values used to calculate limits
this.ChartData.ResetSPCChartData();

//  generate alarms now
this.ChartData.AlarmStateEventEnable = true;
// Must have data loaded before any of the Auto.. methods are called
// Check this data against rules
SimulateData(100, 23);
```

[VB]

```
AddHandler Me.ChartData.AlarmStateEventHandler, AddressOf Me.SPCControlLimitAlarm
' don't generate alarms in initial data simulation
Me.ChartData.AlarmStateEventEnable = False

Me.PrimaryChart.UseWERuntimeRules()
' Me.PrimaryChart.UseWERuntimeAndSupplementalRules()
```

```
SimulateData()

' Calculate the SPC control limits for the X-Bar part of the current SPC chart (X-Bar R)
Me.AutoCalculateControlLimits()
' Scale the y-axis of the X-Bar chart to display all data and control limits
Me.AutoScalePrimaryChartYRange()
' Scale the y-axis of the Range chart to display all data and control limits
Me.AutoScaleSecondaryChartYRange()
' Rebuild the chart using the current data and settings
Me.RebuildChartUsingCurrentData()

'  generate alarms starting now
Me.ChartData.AlarmStateEventEnable = True
```

If you have setup a method for processing alarm events, the software will call the classes alarm processing method, where you can take appropriate action. If a time interval has multiple alarms, i.e. more than one of the four WR Runtime rules are broken, only the one with the lowest WE rule number is vectored to the alarm event processing routine.

[C#]

```
    this.ChartData.AlarmStateEventHandler +=
        new SPCControlLimitAlarmEventDelegate(this.SPCControlLimitAlarm);
    // don't generate alarms in initial data simulation
    this.ChartData.AlarmStateEventEnable = false;

    this.PrimaryChart.UseWERuntimeRules();
    // Must have data loaded before any of the Auto.. methods are called
     SimulateData(100, 20);

    // Calculate the SPC control limits
    this.AutoCalculateControlLimits();

    // throw out values used to calculate limits
    this.ChartData.ResetSPCChartData();

    // generate alarms now
    this.ChartData.AlarmStateEventEnable = true;
    // Must have data loaded before any of the Auto.. methods are called
    // Check this data against rules
    SimulateData(100, 23);
}


private void SPCControlLimitAlarm(object sender, SPCControlLimitAlarmArgs e)
{
    SPCControlLimitRecord alarm = e.EventAlarm;
    double alarmlimitvalue = alarm.ControlLimitValue;
    String alarmlimitvaluestring = alarmlimitvalue.ToString();

    SPCControlChartData spcData = alarm.SPCProcessVar;
    SPCCalculatedValueRecord spcSource = e.SPCSource;
    String calculatedvaluestring = spcSource.CalculatedValue.ToString();

    String message = alarm.AlarmMessage;
    ChartCalendar timestamp = spcData.TimeStamp;
    String timestampstring = timestamp.ToString();

    String notesstring = "\n" + timestampstring + " " + message + "=" + "\n" +
    alarmlimitvaluestring + " Current Value" + "=" + calculatedvaluestring;
    if (alarm.AlarmState)
    //             Console.Out.WriteLine(notesstring);
        this.ChartData.AppendNotesString(notesstring, true);
}
```

[VB]

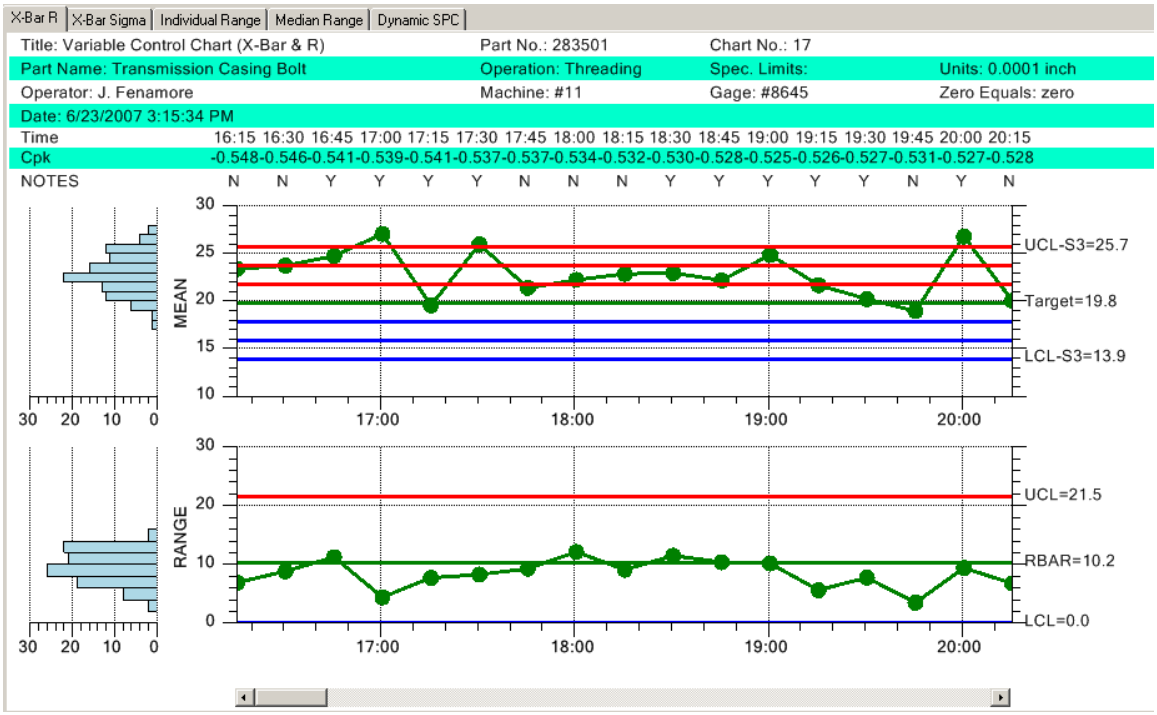
```
 AddHandler Me.ChartData.AlarmStateEventHandler, AddressOf Me.SPCControlLimitAlarm
' don't generate alarms in initial data simulation
  Me.ChartData.AlarmStateEventEnable = False

  Me.PrimaryChart.UseWERuntimeRules()

  SimulateData()

  ' Calculate the SPC control limits for the X-Bar part of the current SPC chart (X-Bar R)
  Me.AutoCalculateControlLimits()
  ' Scale the y-axis of the X-Bar chart to display all data and control limits
  Me.AutoScalePrimaryChartYRange()
  ' Scale the y-axis of the Range chart to display all data and control limits
  Me.AutoScaleSecondaryChartYRange()
  ' Rebuild the chart using the current data and settings
  Me.RebuildChartUsingCurrentData()

  '  generate alarms starting now
  Me.ChartData.AlarmStateEventEnable = True
  End Sub 'SPCControlLimitAlarm
 .
 .
 .

Private Sub SPCControlLimitAlarm(ByVal sender As Object, ByVal e As
SPCControlLimitAlarmArgs)
  Dim alarm As SPCControlLimitRecord = e.EventAlarm
  Dim alarmlimitvalue As Double = alarm.ControlLimitValue
  Dim alarmlimitvaluestring As [String] = alarmlimitvalue.ToString()
  Dim spcData As SPCControlChartData = alarm.SPCProcessVar
  Dim spcSource As SPCCalculatedValueRecord = e.SPCSource
  Dim calculatedvaluestring As [String] = spcSource.CalculatedValue.ToString()

  Dim message As [String] = alarm.AlarmMessage
  Dim timestamp As ChartCalendar = spcData.TimeStamp
  Dim timestampstring As [String] = timestamp.ToString()
  Dim notesstring As String =
       "\n" + timestampstring + " " + message + "=" + "\n" +
       alarmlimitvaluestring + " Current Value" + "=" + calculatedvaluestring

  If alarm.AlarmState Then
     ' Console.Out.WriteLine((timestampstring + " " + message + "=" +
alarmlimitvaluestring + " Current Value" + "=" + calculatedvaluestring))
     Me.ChartData.AppendNotesString(notesstring, True)
  End If
End Sub 'SPCControlLimitAlarm
```

If you want multiple alarms for a time interval vectored to the alarm processing routine (i.e. it is possible that a time period has WE1, WE2, WE3 and WE4 alarms), set the SPCControlChartData property to SPCControlChartData.REPORT_ALL_ALARMS.

```
this.ChartData.AlarmReportMode = SPCControlChartData.REPORT_ALL_ALARMS
```

The resulting X-Bar R SPC Chart with WE Runtime Rules looks something like this. In this example, the WR Rules violations are processed by the **SPCControlLimitAlarm** method, where the alarm condition is added to the Notes record for the appropriate sample interval. The Y in the

Notes line indicates that an alarm record has been saved for that time interval, and you can click on the Y to see the note describing the alarm condition.



Specification Limits

Specification limits are not to be confused with the SPC Control Limits discussed in the previous sections. Specification limits are imposed externally and are not calculated based on the manufacturing process under control. They represent the maximum deviation allowable for the process variable being measured. They are calculated based on input from customers and/or engineering. Usually specification limits are going to be wider than the SPC 3-sigma limits, because you want the SPC control limits to trip before you get to the specification limits. The SPC control limits give you advance notice that the process is going south before you start rejecting parts based on specification limits. You can display specification limits in the same chart as SPC control limits. Use the
AddSpecLimit method of the PrimaryChart or SecondaryChart.

[C#]

```
this.PrimaryChart.AddSpecLimit(SPCChartObjects.SPC_LOWER_SPEC_LIMIT, 18.3, "L
SPEC", new ChartAttribute(Color.Green, 3.0));
this.PrimaryChart.AddSpecLimit(SPCChartObjects.SPC_UPPER_SPEC_LIMIT, 39.1, "H
SPEC", new ChartAttribute(Color.Yellow, 3.0));
```

[VB]

```
Me.PrimaryChart.AddSpecLimit(SPCChartObjects.SPC_LOWER_SPEC_LIMIT, 18.3, "L
SPEC", New ChartAttribute(Color.Green, 3.0))
Me.PrimaryChart.AddSpecLimit(SPCChartObjects.SPC_UPPER_SPEC_LIMIT, 39.1, "H
```

```
SPEC", New ChartAttribute(Color.Yellow, 3.0))
```

Chart Y-Scale

You can set the minimum and maximum values of the two charts y-scales manually using the **PrimaryChart.MinY**, **PrimaryChart.MaxY**, **SecondaryChartMinY** and **SecondaryChartMaxY** properties.

[C#]

```
// Set initial scale of the y-axis of the mean chart
// If you are calling AutoScalePrimaryChartYRange this isn't really needed
    this.PrimaryChart.MinY = 0;
    this.PrimaryChart.MaxY = 40;

// Set initial scale of the y-axis of the range chart
// If you are calling AutoScaleSecondaryChartYRange this isn't really needed
    this.SecondaryChart.MinY = 0;
    this.SecondaryChart.MaxY = 40;
```

[VB]

```
' Set initial scale of the y-axis of the mean chart
' If you are calling AutoScalePrimaryChartYRange this isn't really needed
Me.PrimaryChart.MinY = 0
Me.PrimaryChart.MaxY = 40

' Set initial scale of the y-axis of the range chart
' If you are calling AutoScaleSecondaryChartYRange this isn't really needed
Me.SecondaryChart.MinY = 0
Me.SecondaryChart.MaxY = 40
```

It is easiest to just call the auto-scale routines after the chart has been initialized with data, and any control limits calculated.

[C#]

```
// Must have data loaded before any of the Auto.. methods are called
    SimulateData();

// Calculate the SPC control limits for both graphs of the current SPC chart
    this.AutoCalculateControlLimits();

// Scale the y-axis of the X-Bar chart to display all data and control limits
    this.AutoScalePrimaryChartYRange();
// Scale the y-axis of the Range chart to display all data and control limits
    this.AutoScaleSecondaryChartYRange();
```

[VB]

```
' Must have data loaded before any of the Auto.. methods are called
SimulateData()

' Calculate the SPC control limits for both graphs of the current SPC chart
Me.AutoCalculateControlLimits()

' Scale the y-axis of the X-Bar chart to display all data and control limits
Me.AutoScalePrimaryChartYRange()
' Scale the y-axis of the Range chart to display all data and control limits
Me.AutoScaleSecondaryChartYRange()
```

Once all of the graph parameters are set, call the method **RebuildChartUsingCurrentData**.

[C#]

```
// Rebuild the chart using the current data and settings
this.RebuildChartUsingCurrentData();
```

[VB]

```
// Rebuild the chart using the current data and settings
Me.RebuildChartUsingCurrentData
```

If, at any future time you change any of the chart properties, you will need to call **RebuildChartUsingCurrentData** to force a rebuild of the chart, taking into account the current properties. **RebuildChartUsingCurrentData** also invalidates the chart and forces a redraw. Our examples that update dynamically demonstrate this technique. The chart is setup with some initial settings and data values. As data is added in real-time to the graph, the chart SPC limits, and y-scales are constantly recalculated to take into account new data values. The following code is extracted from the **TimeVariableControlCharts.DynamicXBarRChart** example.

[C#]

```
private void timer1_Tick(object sender, System.EventArgs e)
{
    if (this.IsDesignMode) return;
    ChartCalendar timestamp = (ChartCalendar) startTime.Clone();

    // Use the ChartData sample simulator to make an array of sample data
    DoubleArray samples = this.ChartData.SimulateMeasurementRecord(30);
    // Add the new sample subgroup to the chart
    this.ChartData.AddNewSampleRecord(timestamp, samples);

// Calculate the SPC control limits for the X-Bar part of the current SPC chart
    this.AutoCalculateControlLimits();
// Scale the y-axis of the X-Bar chart to display all data and control limits
    this.AutoScalePrimaryChartYRange();
    // Scale the y-axis of the Range chart to display all data and control limits
    this.AutoScaleSecondaryChartYRange();
    // Rebuild and draw the chart using the current data and settings
    this.RebuildChartUsingCurrentData();
    // Simulate timeincrementminutes  minute passing
    startTime.Add(ChartObj.MINUTE, timeincrementminutes);
}
```

[VB]

```
Private Sub Timer1_Tick(ByVal sender As System.Object, ByVal e As System.EventArgs)
Handles Timer1.Tick
    If Me.IsDesignMode Then
        Return
    End If
    Dim timestamp As ChartCalendar = CType(startTime.Clone(), ChartCalendar)

    ' Use the ChartData sample simulator to make an array of sample data
    Dim samples As DoubleArray = Me.ChartData.SimulateMeasurementRecord(30)
    ' Add the new sample subgroup to the chart
    Me.ChartData.AddNewSampleRecord(timestamp, samples)

' Calculate the SPC control limits for the X-Bar part of the current SPC chart
    Me.AutoCalculateControlLimits()
   ' Scale the y-axis of the X-Bar chart to display all data and control limits
    Me.AutoScalePrimaryChartYRange()
    ' Scale the y-axis of the Range chart to display all data and control limits
```

```
    Me.AutoScaleSecondaryChartYRange()
    ' Rebuild and draw the chart using the current data and settings
    Me.RebuildChartUsingCurrentData()
    ' Simulate timeincrementminutes  minute passing
    startTime.Add(ChartObj.MINUTE, timeincrementminutes)
End Sub
```

Updating Chart Data

The real-time example above demonstrates how the SPC chart data is updated, using the **ChartData.AddNewSampleRecord** method. In this case, the chart data updates with each timer tick event, though it could just as easily be any other type of event. If you have already collected all of your data and just want to plot it all at once, use a simple loop like most of our examples do to update the data.

[C#]

```
private void SimulateData()
{
    for (int i=0; i < 200; i++)
    {
        ChartCalendar timestamp =
        (ChartCalendar) startTime.Clone(); // use this for time row, not graphs
        // Use the ChartData sample simulator to make an array of sample data
        DoubleArray samples = this.ChartData.SimulateMeasurementRecord(33, 9);
        // Add the new sample subgroup to the chart
        this.ChartData.AddNewSampleRecord(timestamp, samples);
        // increment simulated time by timeincrementminutes minutes
        startTime.Add(ChartObj.MINUTE, sampleincrement);
    }
}
```

[VB]

```
Private Sub SimulateData()
   Dim i As Integer
   For i = 0 To 199
      Dim timestamp As ChartCalendar = CType(startTime.Clone(), ChartCalendar)
      ' use this for time row, not graphs
      ' Use the ChartData sample simulator to make an array of sample data
      Dim samples As DoubleArray = Me.ChartData.SimulateMeasurementRecord(33, 9)
      ' Add the new sample subgroup to the chart
      Me.ChartData.AddNewSampleRecord(timestamp, samples)
      ' increment simulated time by timeincrementminutes minutes
      startTime.Add(ChartObj.MINUTE, sampleincrement)
   Next i
End Sub 'SimulateData
```

In this example the sample data and the time stamp for each sample record is simulated. In your application, you will probably be reading the sample record values from some sort of database or file, along with the actual time stamp for that data.

If you want to include a text note in the sample record, use one of the **ChartData.AddNewSampleRecord** overrides that have a *notes* parameter.

[C#]

```
private void SimulateData()
{  String notesstring = "";
    for (int i=0; i < 200; i++)
    {
        ChartCalendar timestamp = (ChartCalendar) startTime.Clone();
```

```
        // Use the ChartData sample simulator to make an array of sample data
        DoubleArray samples = this.ChartData.SimulateMeasurementRecord(30, 10);
        double r = ChartSupport.GetRandomDouble();
        if (r < 0.1) // make a note on every tenth item, on average
        notesstring = "Note for sample subgroup #" +
                      i.ToString() +
                      ". This sample is flagged as having some sort of problem";
               else
                   notesstring = "";
               // Add the new sample subgroup to the chart
        this.ChartData.AddNewSampleRecord(timestamp, samples, notesstring);
        // increment simulated time by timeincrementminutes minutes
        startTime.Add(ChartObj.MINUTE, timeincrementminutes);
    }
}
```

[VB]

```
Private Sub SimulateData()
   Dim notesstring As [String] = ""
   Dim i As Integer
   For i = 0 To 199
      Dim timestamp As ChartCalendar = CType(startTime.Clone(), ChartCalendar)
      ' Use the ChartData sample simulator to make an array of sample data
      Dim samples As DoubleArray = Me.ChartData.SimulateMeasurementRecord(30, 10)
      Dim r As Double = ChartSupport.GetRandomDouble()
      If r < 0.1 Then ' make a note on every tenth item, on average
         notesstring = "Note for sample subgroup #" + i.ToString() + _
                       ". This sample is flagged as having some sort of problem"
      Else
         notesstring = ""
      End If ' Add the new sample subgroup to the chart
      Me.ChartData.AddNewSampleRecord(timestamp, samples, notesstring)
      ' increment simulated time by timeincrementminutes minutes
      startTime.Add(ChartObj.MINUTE, timeincrementminutes)
   Next i
End Sub 'SimulateData
```

There are situations where you might want to add, change, modify, or append a note for a sample subgroup after the **AddNewSampleRecord** method has already been called for the sample subgroup. This can happen if the **AddNewSampleRecord** method call generates an alarm event. In the alarm event processing routine, you can add code that adds a special note to the sample subgroup that generated the alarm. Use the **ChartData.SetNotesString** or **ChartData.AppendNotesString** methods to add notes to the current record, separate from the **AddNewSampleRecord** method.

Extracted from the VariableControlCharts.DynamicXBarRChart example program.

[C#]

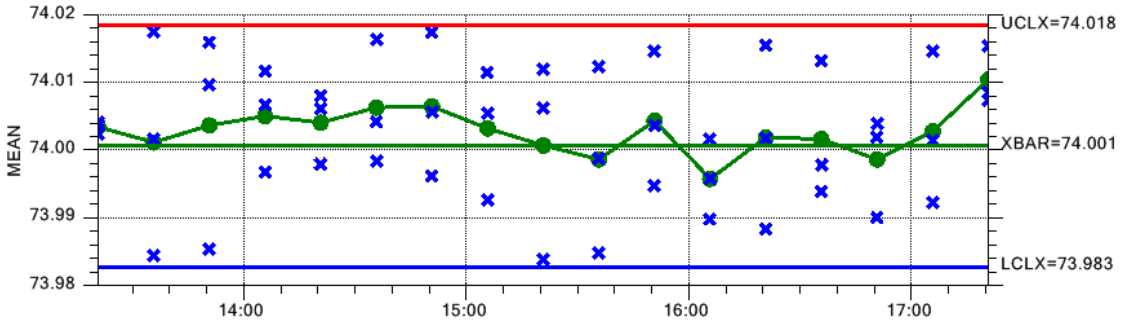
```
private void SPCControlLimitAlarm(object sender, SPCControlLimitAlarmArgs e)
{
    SPCControlLimitRecord alarm = e.EventAlarm;
    double alarmlimitvalue = alarm.ControlLimitValue;
    String alarmlimitvaluestring = alarmlimitvalue.ToString();

    SPCControlChartData spcData = alarm.SPCProcessVar;
     SPCCalculatedValueRecord spcSource = e.SPCSource;
    String calculatedvaluestring = spcSource.CalculatedValue.ToString();

    String message = alarm.AlarmMessage;
    ChartCalendar timestamp = spcData.TimeStamp;
    String timestampstring = timestamp.ToString();
```

```
    String notesstring = "\n" + timestampstring + " " + message + "=" +
        "\n" +  alarmlimitvaluestring + " Current Value" + "=" +
        calculatedvaluestring;

// Append a notes string to the current record.
    if (alarm.AlarmState)
      this.ChartData.AppnedNotesString(notesstring, true);

}
```

[VB]

```
Private Sub SPCControlLimitAlarm(ByVal sender As Object, ByVal e As
SPCControlLimitAlarmArgs)
   Dim alarm As SPCControlLimitRecord = e.EventAlarm
   Dim alarmlimitvalue As Double = alarm.ControlLimitValue
   Dim alarmlimitvaluestring As [String] = alarmlimitvalue.ToString()

   Dim spcData As SPCControlChartData = alarm.SPCProcessVar
   Dim spcSource As SPCCalculatedValueRecord = e.SPCSource
   Dim calculatedvaluestring As [String] = spcSource.CalculatedValue.ToString()

   Dim message As [String] = alarm.AlarmMessage
   Dim timestamp As ChartCalendar = spcData.TimeStamp
   Dim timestampstring As [String] = timestamp.ToString()
   Dim notesstring As String = "\n" + timestampstring + " " + message _
    + "=" + "\n" +   alarmlimitvaluestring + " Current Value" + "=" +  _
    calculatedvaluestring

   If alarm.AlarmState Then
      Me.ChartData.AppendNotesString(notesstring, True)
   End If
End Sub 'SPCControlLimitAlarm
```

Scatter Plots of the Actual Sampled Data



If you want the actual sample data plotted along with the mean or median of the sample data, set the **PrimaryChart.PlotMeasurementValues** to true.

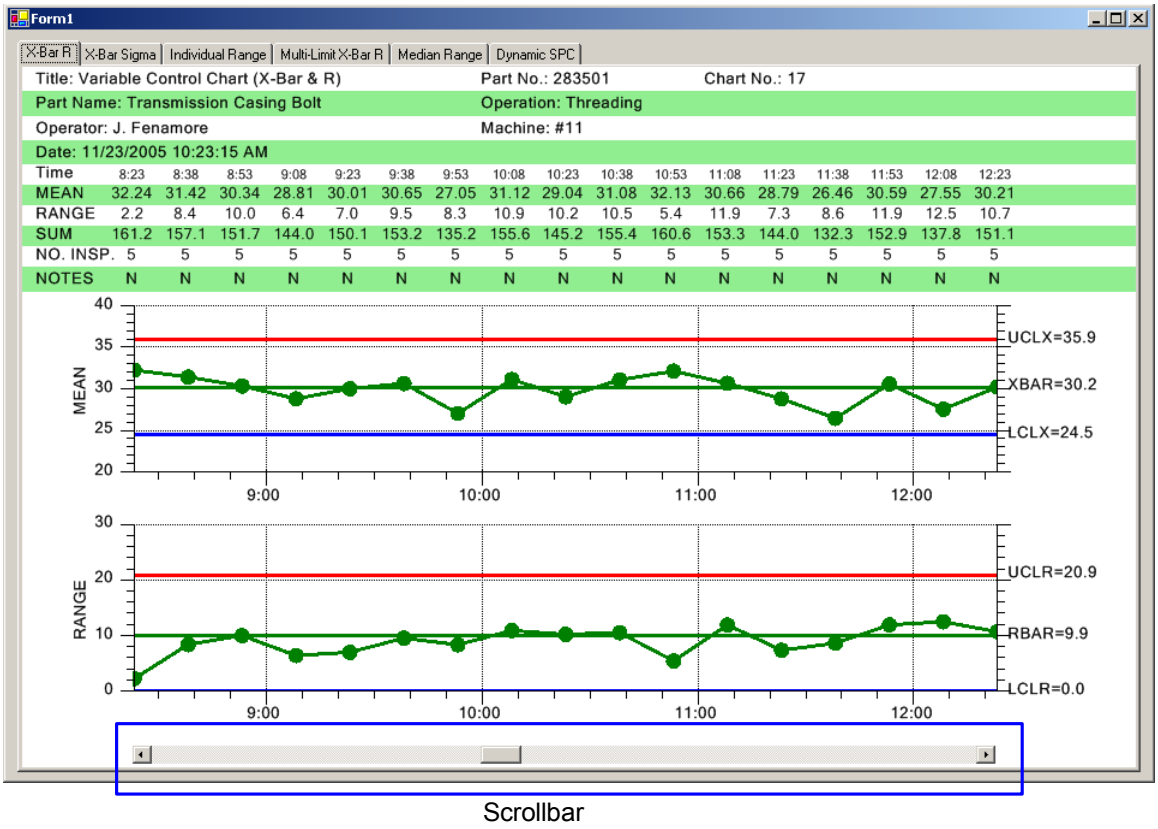
[C#]

```
// Plot individual sampled values as a scatter plot
this.PrimaryChart.PlotMeasurementValues = true;
```

[VB]

```
' Plot individual sampled values as a scatter plot
Me.PrimaryChart.PlotMeasurementValues = True
```

Enable the Chart ScrollBar



Set the **EnableScrollBar** property true to enable the chart scrollbar. You will then be able to window in on 8-20 sample subgroups at a time, from a much larger collection of measurement data representing hundreds or even thousands of subgroups, and use the scrollbar to move through the data, similar to paging through a spreadsheet.

[C#]

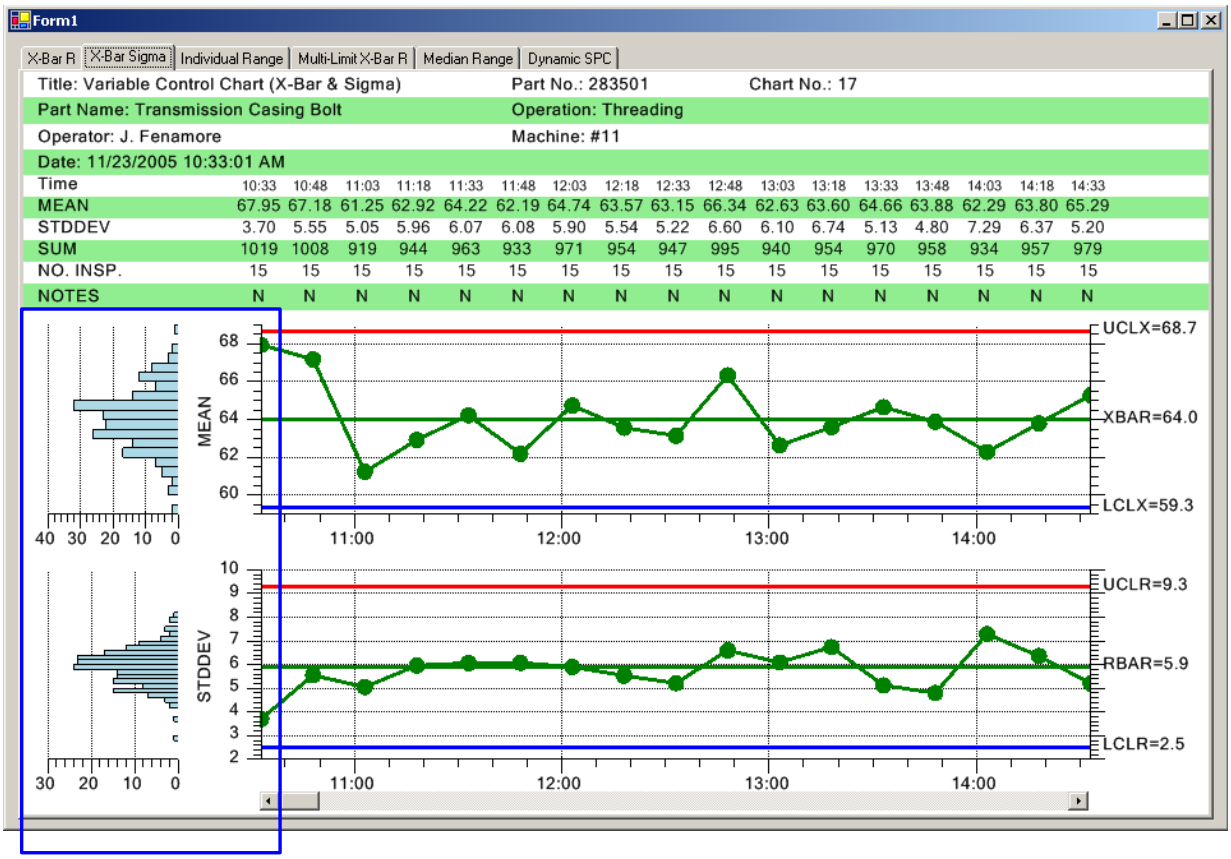
```
// enable scroll bar
this.EnableScrollBar = true;
```

[VB]

```
' enable scroll bar
Me.EnableScrollBar = True
```

Once you have initialized the chart with data, and the scrollbar has a range associated with it, you can access the scrollbar using the charts **`HScrollBar1`** `property.`

SPC Chart Histograms



Frequency Histograms

Viewing frequency histograms of both the variation in the primary variable (Mean, Median, count, or actual value), and the secondary variable (Range, Sigma or Moving Range) side-by-side with the SPC control chart makes it even easier to find out whether the variations are the result of natural variations or the result of some systemic change in the process. You can turn on integrated frequency histograms for either chart using the **PrimaryChart.DisplayFrequencyHistogram** and **SecondaryChart.DisplayFrequencyHistogram** properties of the chart.

[C#]

```
//  frequency histogram for both charts
this.PrimaryChart.DisplayFrequencyHistogram = true;
this.SecondaryChart.DisplayFrequencyHistogram = true;
```

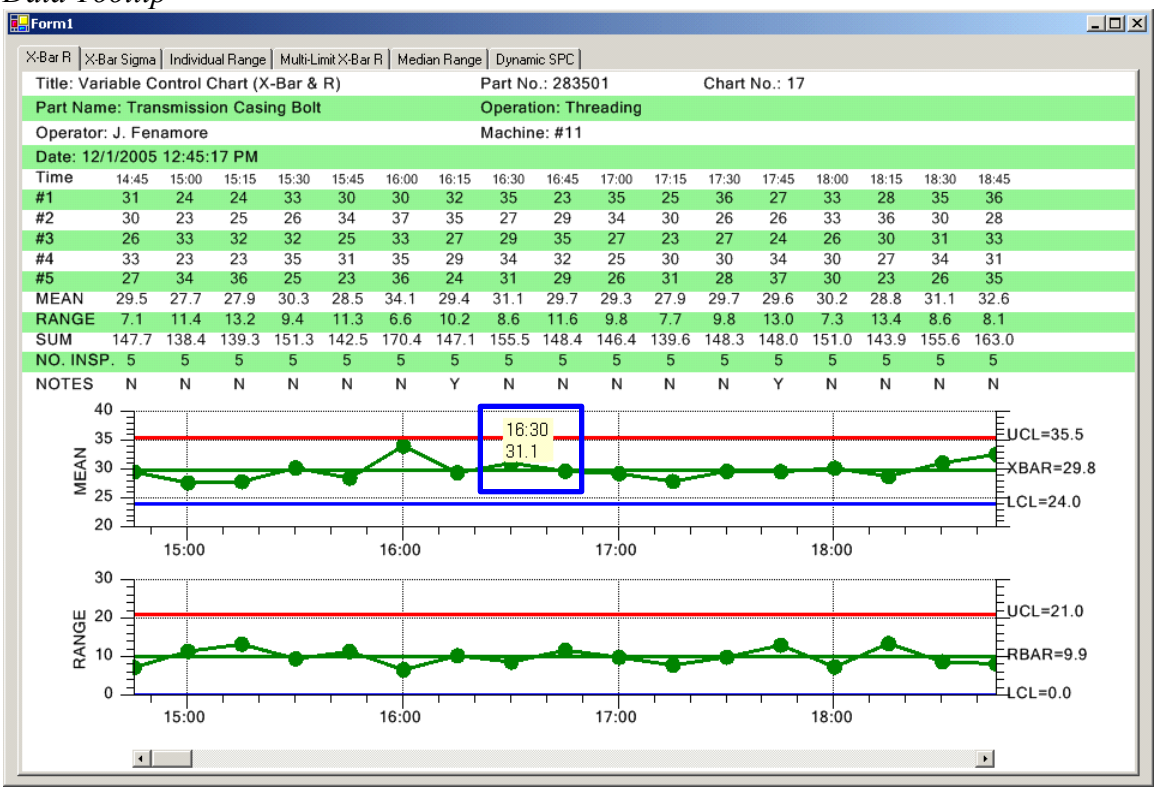
[VB]

```
'  frequency histogram for both charts
Me.PrimaryChart.DisplayFrequencyHistogram = True
Me.SecondaryChart.DisplayFrequencyHistogram = True
```

SPC Chart Data and Notes Tooltips

You can invoke two types of tooltips using the mouse. The first is a data tooltip. When you hold the mouse button down over one of the data points, in the primary or secondary chart, the x and y values for that data point display in a popup tooltip.

Data Tooltip



In the default mode, the data tooltip displays the x,y value of the data point nearest the mouse click. If the x-axis is a time axis then the x-value is displayed as a time stamp; otherwise, it is displayed as a simple numeric value, as is the y-value. You can optionally display subgroup information (sample values, calculated values, process capability values and notes) in the data tooltip window, under the x,y value, using enable flags in the primary charts tooltip property.

Extracted from the TimeVariableControlCharts.XBarRChart example.

[C#]

```
this.PrimaryChart.Datatooltip.EnableCategoryValues = true;
this.PrimaryChart.Datatooltip.EnableProcessCapabilityValues = true;
this.PrimaryChart.Datatooltip.EnableCalculatedValues = true;
this.PrimaryChart.Datatooltip.EnableNotesString = true;
```

[VB]

```
Me.PrimaryChart.Datatooltip.EnableCategoryValues = True
Me.PrimaryChart.Datatooltip.EnableProcessCapabilityValues = True
Me.PrimaryChart.Datatooltip.EnableCalculatedValues = True
Me.PrimaryChart.Datatooltip.EnableNotesString = True
```

where

The following properties enable sections of the chart header and table:

PrimaryChart.Datatooltip.EnableCategoryValues
PrimaryChart.Datatooltip.EnableProcessCapabilityValues
PrimaryChart.Datatooltip.EnableCalculatedValues
PrimaryChart.Datatooltip.EnableNotesStrings

Display the category (subgroup sample values) in the data tooltip.
`PrimaryChart.Datatooltip.EnableCategoryValues = true`

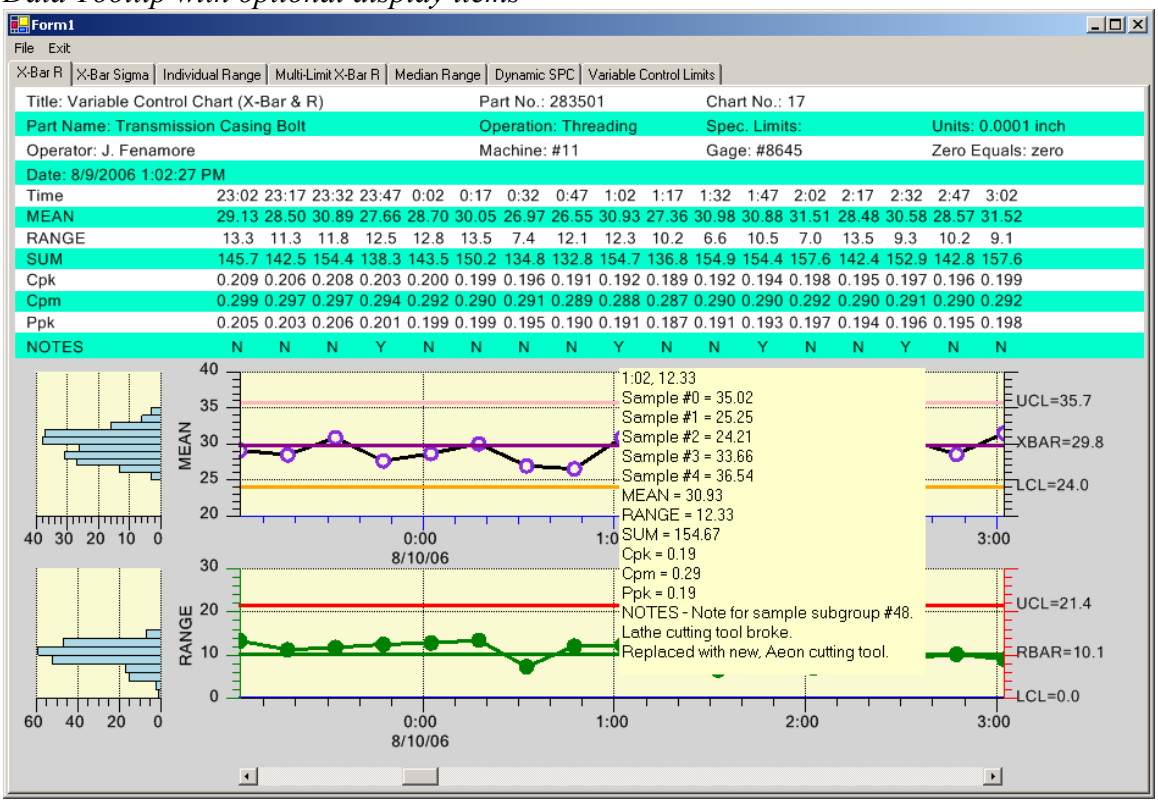
Display the calculated values used in the chart (Mean, range and sum for an Mean-Range chart).
`PrimaryChart.Datatooltip.EnableCalculatedValues = true`

Display the process capability (Cp, Cpl, Cpu, Cpk, Cpm, Pp, Ppl, Ppu and Ppk) statistics currently being calculated for the chart.
`PrimaryChart.Datatooltip.EnableProcessCapabilityValues = true`

Display the current notes string for the sample subgroup.
`PrimaryChart.Datatooltip.EnableNotesString = true`

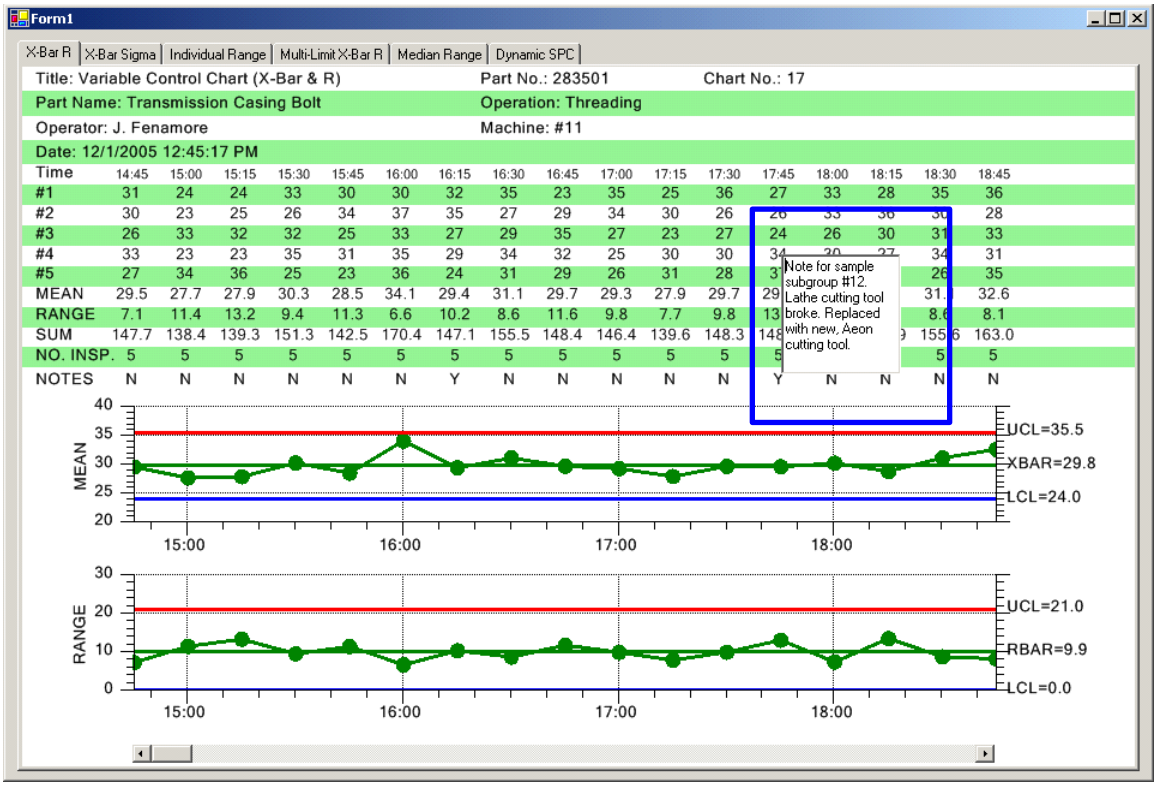
The variable control chart below displays a tooltip with all of the enable options above set true.

Data Tooltip with optional display items



If you are displaying the Notes line in the table portion of the chart, the Notes entry for a sample subgroup will display “Y” if a note was recorded for that sample subgroup, or “N” if no note was recorded. Notes are recorded using one of the **ChartData.AddNewSampleRecord** overrides that include a notes parameter, or by using the **ChartData.SetNotes**, or **ChartData.AppendNotes** methods. See the section *Updating Chart Data*. If you click on a “Y” in the Notes row for a sample subgroup, the complete text of the note for that sample subgroup will display in a RichTextBox, immediately above the “Y”. You can actually edit the notes in the RichTextBox.

Notes Tooltip



[C#]

```
private void SimulateData()
{  String notesstring = "";
    for (int i=0; i < 200; i++)
    {
        .
        .
        .
        this.ChartData.AddNewSampleRecord(timestamp, samples, notesstring);
        // increment simulated time by timeincrementminutes minutes
        startTime.Add(ChartObj.MINUTE, timeincrementminutes);
    }
}
```

[VB]

```
Private Sub SimulateData()
```

```
   Dim notesstring As [String] = ""
   Dim i As Integer
   For i = 0 To 199
        .
        .
        .
      Me.ChartData.AddNewSampleRecord(timestamp, samples, notesstring)
      ' increment simulated time by timeincrementminutes minutes
      startTime.Add(ChartObj.MINUTE, timeincrementminutes)
   Next i
End Sub 'SimulateData
```

Both kinds of tooltips are on by default. Turn the tooltips on or off in the program using the **EnableDataToolTip** and **EnableNotesToolTip** flags.

[C#]

```
// Enable data and notes tooltips
this.EnableDataToolTip = true;
this.EnableNotesToolTip = true;
```

[VB]

```
' Enable data and notes tooltips
Me.EnableDataToolTip = True
Me.EnableNotesToolTip = True
```

The notes tooltip has an additional option. In order to make the notes tooltip “editable”, the tooltip, which is .Net RichEditBox, displays on the first click, and goes away on the second click. You can click inside the RichTextBox and not worry the tooltip suddenly disappearing. The notes tooltip works this way by default. If you wish to explicitly set it, or change it so that the tooltip only displays while the mouse button is held down, as the data tooltips do, set the **ChartData.NotesToolTips.ToolTipMode** property to **NotesToolTip.MOUSEDOWN_TOOLTIP**, as in the example below.

[C#]

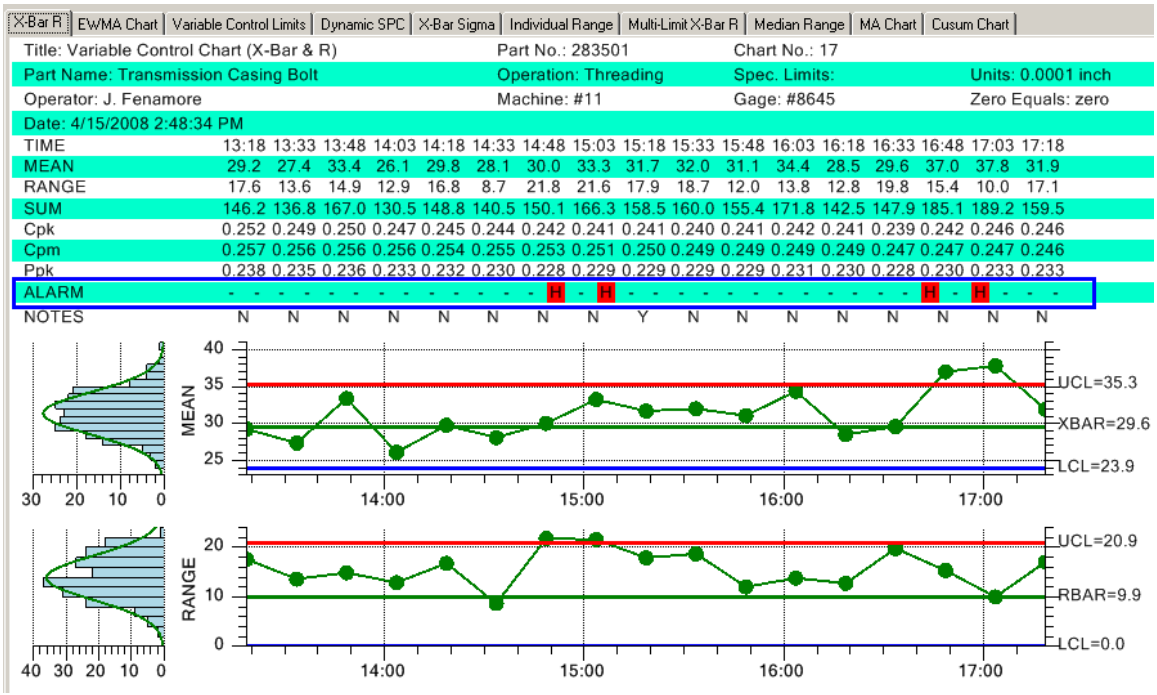
```
// Enable data and notes tooltips
this.EnableDataToolTip = true;
this.EnableNotesToolTip = true;

this.ChartData.NotesToolTips.ButtonMask = MouseButtons.Right;
// default is MOUSETOGGLE_TOOLTIP
this.ChartData.NotesToolTips.ToolTipMode= NotesToolTip.MOUSEDOWN_TOOLTIP;
```

[VB]

```
' Enable data and notes tooltips
Me.EnableDataToolTip = True
Me.EnableNotesToolTip = True

Me.ChartData.NotesToolTips.ButtonMask = MouseButtons.Right
' default is MOUSETOGGLE_TOOLTIP
Me.ChartData.NotesToolTips.ToolTipMode = NotesToolTip.MOUSEDOWN_TOOLTIP
```

Enable Alarm Highlighting

EnableAlarmStatusValues



There are several alarm highlighting options you can turn on and off. The alarm status line above is turned on/off using the EnableAlarmStatusValues property. We have set it on by default, so you will have to turn it off if you don't want it. Each sample interval has two small boxes that are labeled using one of three different characters. An "H" signifies a high alarm, a "L" signifies a low alarm, and a "-" signifies that there is no alarm.

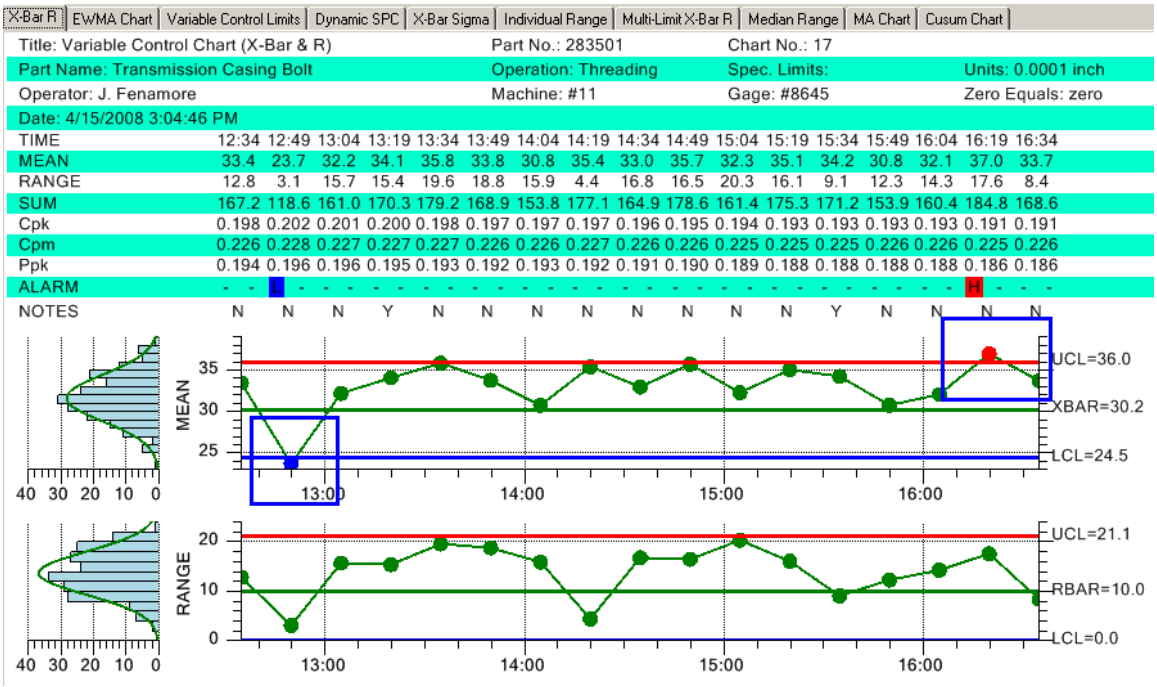
[C#]

```
// Alarm status line
this.EnableAlarmStatusValues = false;
```

[VB]

```
'Alarm status line
Me.EnableAlarmStatusValues = False
```

ChartAlarmEmphasisMode



[C#]

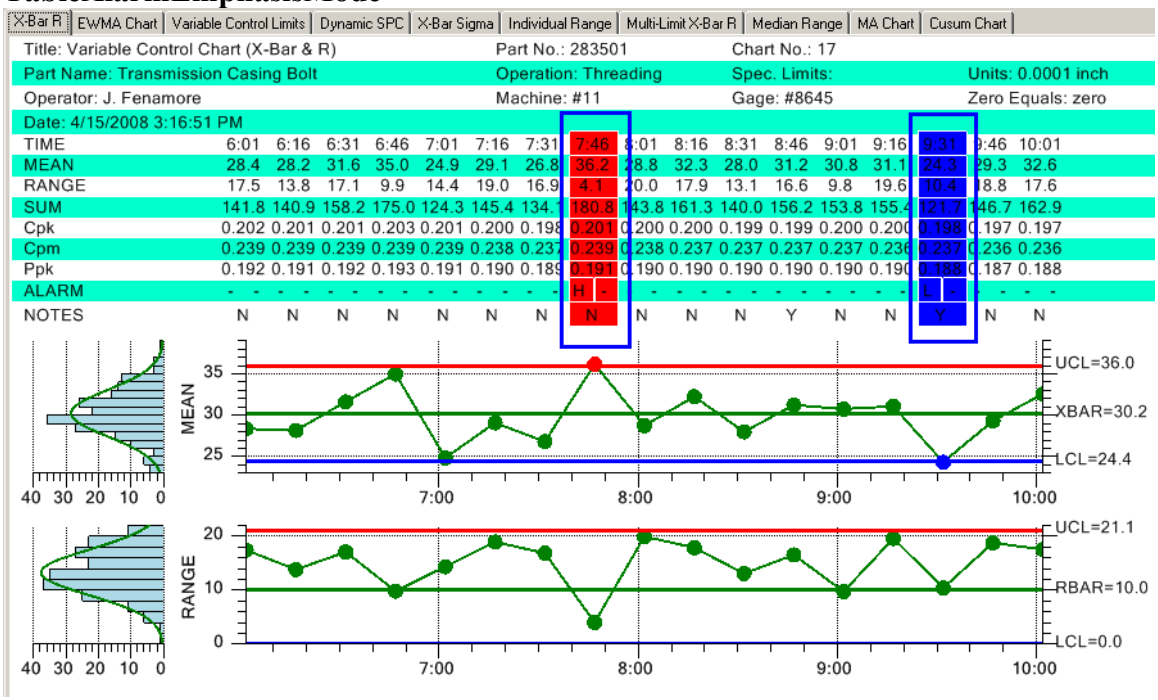
```
// Chart alarm emphasis mode
this.ChartAlarmEmphasisMode = SPCChartBase.ALARM_HIGHLIGHT_SYMBOL;
```

[VB]

```
' Chart alarm emphasis mode
Me.ChartAlarmEmphasisMode = SPCChartBase.ALARM_HIGHLIGHT_SYMBOL
```

The scatter plot symbol used to plot a data point in the primary and secondary charts is normally a fixed color circle. If you turn on the alarm highlighting for chart symbols the symbol color for a sample interval that is in an alarm condition will change to reflect the color of the associated alarm line. In the example above, a low alarm (blue circle) occurs at the beginning of the chart and a high alarm (red circle) occurs at the end of the chart. Alarm symbol highlighting is turned on by default. To turn it off use the SPCChartBase.ALARM_NO_HIGHLIGHT_SYMBOL constants.

TableAlarmEmphasisMode -



C#]

```
// Table alarm emphasis mode
this.TableAlarmEmphasisMode = SPCChartBase.ALARM_HIGHLIGHT_BAR;
```

[VB]

```
' Table alarm emphasis mode
Me.TableAlarmEmphasisMode = SPCChartBase.ALARM_HIGHLIGHT_BAR
```

The entire column of the data table can be highlighted when an alarm occurs. There are four modes associated with this property:

ALARM_HIGHLIGHT_NONE	No alarm highlight
ALARM_HIGHLIGHT_TEXT	Text alarm highlight
ALARM_HIGHLIGHT_OUTLINE	Outline alarm highlight
ALARM_HIGHLIGHT_BAR	Bar alarm highlight

The example above uses the ALARM_HIGHLIGHT_BAR mode.

Title: Variable Control Chart (X-Bar & R)						Part No.: 283501				Chart No.: 17							
Part Name: Transmission Casing Bolt						Operation: Threading				Spec. Limits:						Units: 0.0001 inch	
Operator: J. Fenamore						Machine: #11				Gage: #8645						Zero Equals: zero	
Date: 4/15/2008 4:08:49 PM																	
TIME	6:23	6:38	6:53	7:08	7:23	7:38	7:53	8:08	8:23	8:38	8:53	9:08	9:23	9:38	9:53	10:08	10:23
MEAN	32.0	28.2	32.5	23.2	26.5	30.2	26.6	28.4	36.5	28.7	27.7	28.8	29.3	30.0	35.0	27.3	30.0
RANGE	16.7	17.6	16.7	12.3	15.0	14.7	17.8	16.9	15.7	15.9	21.1	9.8	19.3	19.0	11.7	14.5	17.7
SUM	160.2	141.0	162.5	116.1	132.3	151.1	132.9	142.0	182.6	143.3	138.6	143.8	146.4	150.0	175.2	136.5	150.0
Cpk	0.173	0.172	0.173	0.170	0.169	0.169	0.167	0.167	0.169	0.168	0.167	0.167	0.166	0.166	0.168	0.167	0.166
Cpm	0.229	0.228	0.228	0.228	0.227	0.227	0.227	0.226	0.226	0.226	0.225	0.225	0.225	0.224	0.225	0.225	0.224
Ppk	0.168	0.167	0.168	0.165	0.164	0.164	0.162	0.162	0.163	0.163	0.162	0.162	0.161	0.161	0.163	0.162	0.161
ALARM	-	-	-	-	-	-	L	-	-	-	-	-	-	-	-	-	-	-	-
NOTES	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N

The example above uses the ALARM_HIGHLIGHT_TEXT mode

Title: Variable Control Chart (X-Bar & R)						Part No.: 283501				Chart No.: 17							
Part Name: Transmission Casing Bolt						Operation: Threading				Spec. Limits:						Units: 0.0001 inch	
Operator: J. Fenamore						Machine: #11				Gage: #8645						Zero Equals: zero	
Date: 4/15/2008 4:11:27 PM																	
TIME	12:41	12:56	13:11	13:26	13:41	13:56	14:11	14:26	14:41	14:56	15:11	15:26	15:41	15:56	16:11	16:26	16:41
MEAN	24.3	29.8	29.5	33.1	30.4	28.8	37.4	25.5	29.2	24.6	26.2	29.5	31.1	28.6	31.1	27.6	34.7
RANGE	9.2	19.1	17.4	12.7	12.6	12.0	10.5	20.0	16.7	16.4	16.4	13.2	16.9	16.2	12.1	19.3	8.1
SUM	121.6	149.1	147.5	165.6	152.1	143.8	187.1	127.6	145.8	123.2	131.1	147.5	155.3	142.9	155.5	138.1	173.4
Cpk	0.188	0.188	0.187	0.188	0.188	0.188	0.190	0.189	0.188	0.186	0.185	0.184	0.184	0.184	0.184	0.183	0.185
Cpm	0.226	0.226	0.225	0.225	0.225	0.226	0.226	0.225	0.225	0.225	0.224	0.224	0.224	0.224	0.224	0.223	0.224
Ppk	0.184	0.183	0.183	0.184	0.184	0.184	0.186	0.184	0.183	0.181	0.180	0.180	0.180	0.179	0.179	0.178	0.180
ALARM	L	-	-	-	-	-	-	-	-	-	H	-	-	-	-	-	-	-	-	-	-	-	-	-	-
NOTES	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N

The example above uses the ALARM_HIGHLIGHT_OUTLINE mode. In the table above, the column outlines in blue and red reflect what is actually displayed in the chart, whereas in the other TableAlarmEmphasisMode examples the outline just shows where the alarm highlighting occurs.

The default mode is ALARM_HIGHLIGHT_NONE mode.

AutoLogAlarmsAsNotes

When an alarm occurs, details of the alarm can be automatically logged as a Notes record. Just set the AutoLogAlarmsAsNotes property to true.

[C#]
```
this.AutoLogAlarmsAsNotes = true;
```

[VB]
```
Me.AutoLogAlarmsAsNotes = True
```

Creating a Batch-Based Variable Control Chart

Both the **SPCTimeVariableContolChart** and **SPCBatchVariableControlChart** derive from the **SPCChartBase** and as a result, the two classes are very similar and share 95% of the same properties. Creating and initializing a batch-based SPC chart is much the same as that of a time-based SPC chart. See the example program BatchVariableControlCharts for a variety of batch SPC charts. Derive your base class from the **SPCBatchVariableControlChart** class.

[C#]
```
public class BatchXBarRChart : SPCBatchVariableControlChart
{
    ChartCalendar startTime = new ChartCalendar();
    //  SPC variable control chart type
    int charttype = SPCControlChartData.MEAN_RANGE_CHART;
    // Number of samples per sub group
    int numsamplespersubgroup = 3;
    // Number of data points  in the view
    int numdatapointsinview = 17;
    // The time increment between adjacent subgroups
```

```
    int timeincrementminutes = 15;

    public BatchXBarRChart()
    {
        // This call is required by the Windows.Forms Form Designer.
        InitializeComponent();
        this.Dock = DockStyle.Fill;
        DrawChart();
    }

    public  void DrawChart()
    {
        // Initialize the SPCBatchVariableControlChart
        this.InitSPCBatchVariableControlChart(charttype,
            numsamplespersubgroup, numdatapointsinview);
        // Change the default horizontal position and width of the chart
        .
        .
        .

        this.RebuildChartUsingCurrentData();
    }
}
```

[VB]

```
Public Class BatchXBarRChart
    Inherits com.quinncurtis.spcchartnet.SPCBatchVariableControlChart

#Region " Windows Form Designer generated code "
    Public Sub New()
        MyBase.New()

        'This call is required by the Windows Form Designer.
        InitializeComponent()

        'Add any initialization after the InitializeComponent() call
        Me.Dock = DockStyle.Fill
        DrawChart()

    End Sub
    .
    .
    .
#End Region

Dim startTime As New ChartCalendar()
'  SPC variable control chart type
Dim charttype As Integer = SPCControlChartData.MEAN_RANGE_CHART
' Number of samples per sub group
Dim numsamplespersubgroup As Integer = 3
' Number of data points  in the view
Dim numdatapointsinview As Integer = 17
' The time increment between adjacent subgroups
Dim timeincrementminutes As Integer = 15

Public Sub DrawChart()
 ' Initialize the SPCBatchVariableControlChart
     Me.InitSPCBatchVariableControlChart(charttype, _
        numsamplespersubgroup, numdatapointsinview)
    .
    .
    .

    Me.RebuildChartUsingCurrentData()
End Sub 'DrawChart
```

Establish the control chart type (Mean Range (X-Bar R), Median Range, X-Bar Sigma (Mean Sigma), Individual Range, EWMA, MA, or CuSum) using the variable control charts

InitSPCBatchVariableControlChart (or **InitSPCBatchCusumControlChart** if you are creating a cusum chart) initialization routine. Note that the X-Bar Sigma chart, with a variable subgroup sample size, is initialized using **InitSPCBatchVariableControlChart** with a *charttype* value of MEAN_SIGMA_CHART_VSS. X-Bar Sigma charts with sub groups that use a variable sample size must be updated properly.

SPCBatchVariableControlChart.InitSPCBatchVariableControlChart Method

This initialization method initializes the most important values in the creation of a SPC chart.

[VB]
```
Overloads Public Sub InitSPCBatchVariableControlChart( _
   ByVal charttype As Integer, _
   ByVal numsamplespersubgroup As Integer, _
   ByVal numdatapointsinview As Integer, _
)
```

[C#]
```
public void InitSPCBatchVariableControlChart(
   int charttype,
   int numsamplespersubgroup,
   int numdatapointsinview,
);
```

Parameters

charttype

The SPC chart type parameter. Use one of the SPCControlChartData SPC chart types: MEAN_RANGE_CHART, MEDIAN_RANGE_CHART, MEAN_SIGMA_CHART, MEAN_SIGMA_CHART_VSS, INDIVIDUAL_RANGE_CHART, EWMA_CHART, MA_CHART, MAMR_CHART, MAMS_CHART or TABCUSUM_CHART.

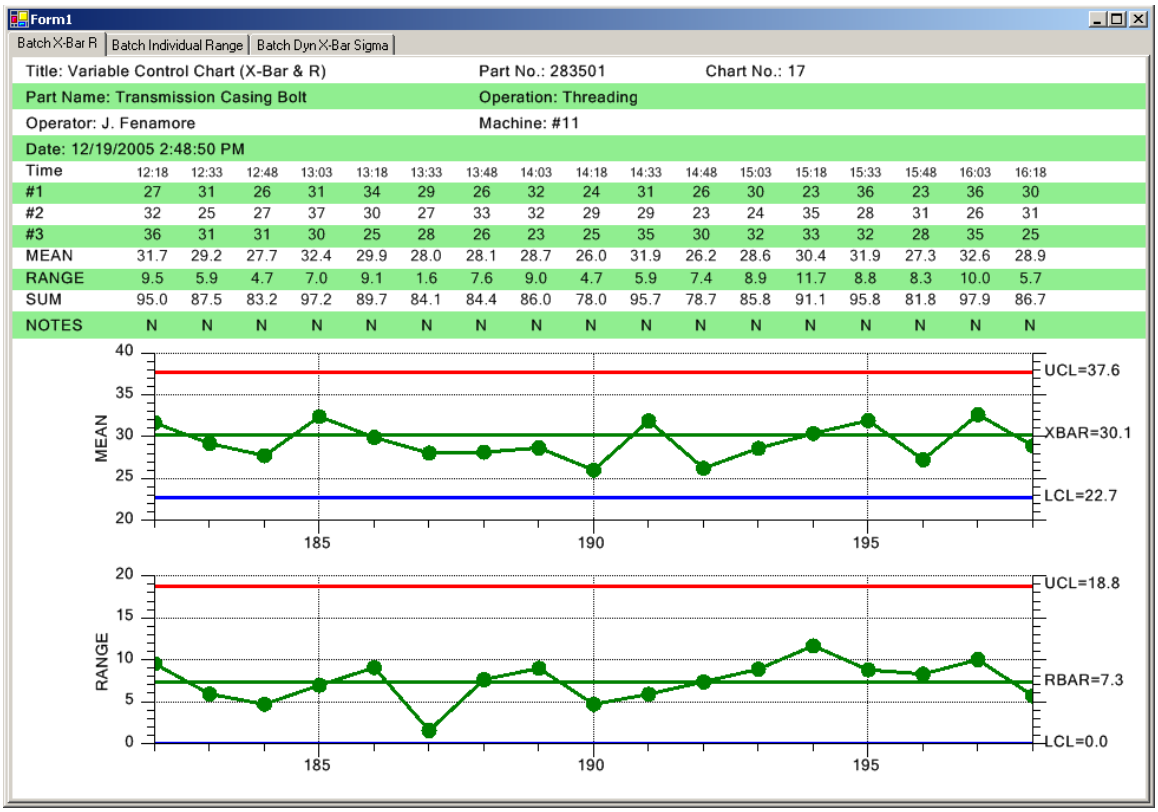
numsamplespersubgroup

Specifies the number of samples that make up a sample subgroup.

numdatapointsinview

Specifies the number of sample subgroups displayed in the graph at one time.

Update the chart data using a **ChartData.AddNewSampleRecord** override that has the batch number (*batchCounter* below) as the first parameter. Even though a time stamp value is also used in the **AddNewSampleRecord** method, it is not used in the actual graph. Instead, it is used as the time stamp for the batch in the table portion of the chart. The following code is extracted from the **BatchVariableControlChart. BatchDynXBarSigmaChart** example program**.**



[C#]

```
private void SimulateData()
{
    // batch number for a given sample subgroup
    int batchCounter = 0;
    for (int i=0; i < 200; i++)
    {
        // Important to make a new ChartCalendar object each time
       ChartCalendar timestamp = (ChartCalendar) startTime.Clone();
        // Simulate a sample subgroup record
        DoubleArray samples = this.ChartData.SimulateMeasurementRecord(30, 10);
        // Update chart data using i as the batch number
        batchCounter = i;
        // Add a new sample record to the chart data
        this.ChartData.AddNewSampleRecord(batchCounter, timestamp, samples);
        // Simulate passage of timeincrementminutes minutes
        startTime.Add(ChartObj.MINUTE, timeincrementminutes);
    }
}
```

[VB]

```
Private Sub SimulateData()
   ' batch number for a given sample subgroup
   Dim batchCounter As Integer = 0
   Dim i As Integer
   For i = 0 To 199
      ' Important to make a new ChartCalendar object each time
      Dim timestamp As ChartCalendar = CType(startTime.Clone(), ChartCalendar)
      ' Simulate a sample subgroup record
      Dim samples As DoubleArray = Me.ChartData.SimulateMeasurementRecord(30, 10)
      ' Update chart data using i as the batch number
      batchCounter = i
      ' Add a new sample record to the chart data
      Me.ChartData.AddNewSampleRecord(batchCounter, timestamp, samples)
      ' Simulate passage of timeincrementminutes minutes
      startTime.Add(ChartObj.MINUTE, timeincrementminutes)
```

```
   Next i
End Sub 'SimulateData
```

Changing the Batch Control Chart X-Axis Labeling Mode

In revisions prior to 2.0, the x-axis tick marks of a batch control chart could only be labeled with the numeric batch number of the sample subgroup. While batch number labeling is still the default mode, it is now possible to label the sample subgroup tick marks using the time stamp of the sample subgroup, or a user-defined string unique to each sample subgroup.

You may find that labeling every subgroup tick mark with a time stamp, or a user-defined string, causes the axis labels to stagger because there is not enough room to display the tick mark label without overlapping its neighbor. In these cases you may wish to reduce the number of sample subgroups you show on the page using the *numdatapointsinview* variable found in all of the example programs.

```
// Number of datapoints in the view
int numdatapointsinview = 13;
```

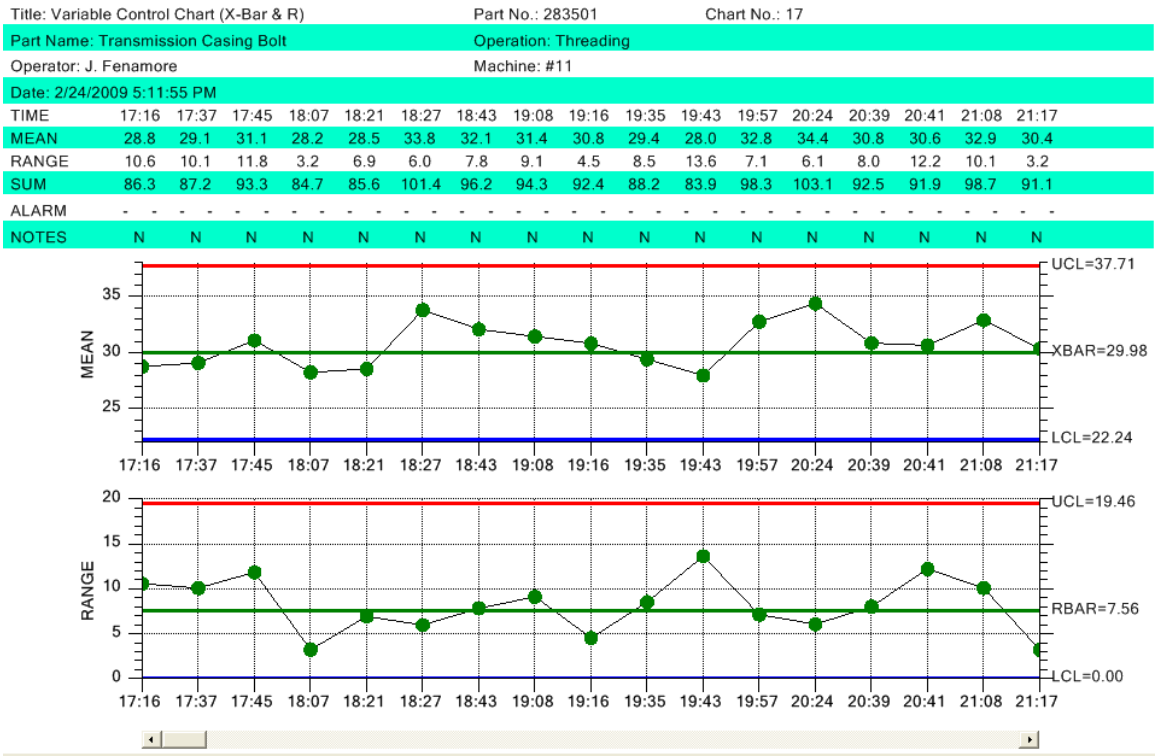
You can rotate the x-axis labels using the charts XAxisLabelRotation property.

```
C#
this.XAxisLabelRotation = 90;

VB
Me.XAxisLabelRotation = 90
```

If you rotate the x-axis labels you may need to leave more room between the primary and secondary graphs, and at the bottom, to allow for the increased height of the labels.

```
C#
this.XAxisLabelRotation = 90;
this.InterGraphMargin = 0.1;
this.GraphBottomPos = 0.85;

VB
Me.XAxisLabelRotation = 90
Me.InterGraphMargin = 0.1
Me.GraphBottomPos = 0.85
```

Batch Control Chart X-Axis Time Stamp Labeling



Batch X-Bar R Chart using time stamp labeling of the x-axis

Set the x-axis labeling mode using the overall charts XAxisStringLabelMode property, setting it `SPCChartObjects.AXIS_LABEL_MODE_TIME`.

[C#]
```
// enable scroll bar
this.EnableScrollBar = true;
this.EnableCategoryValues = false;

// Label the tick mark with time stamp of sample group
this.XAxisStringLabelMode = SPCChartObjects.AXIS_LABEL_MODE_TIME;
```

[VB]
```
' enable scroll bar
Me.EnableScrollBar = True
Me.EnableCategoryValues = False

' Label the tick mark with time stamp of sample group
Me.XAxisStringLabelMode = SPCChartObjects.AXIS_LABEL_MODE_TIME
```

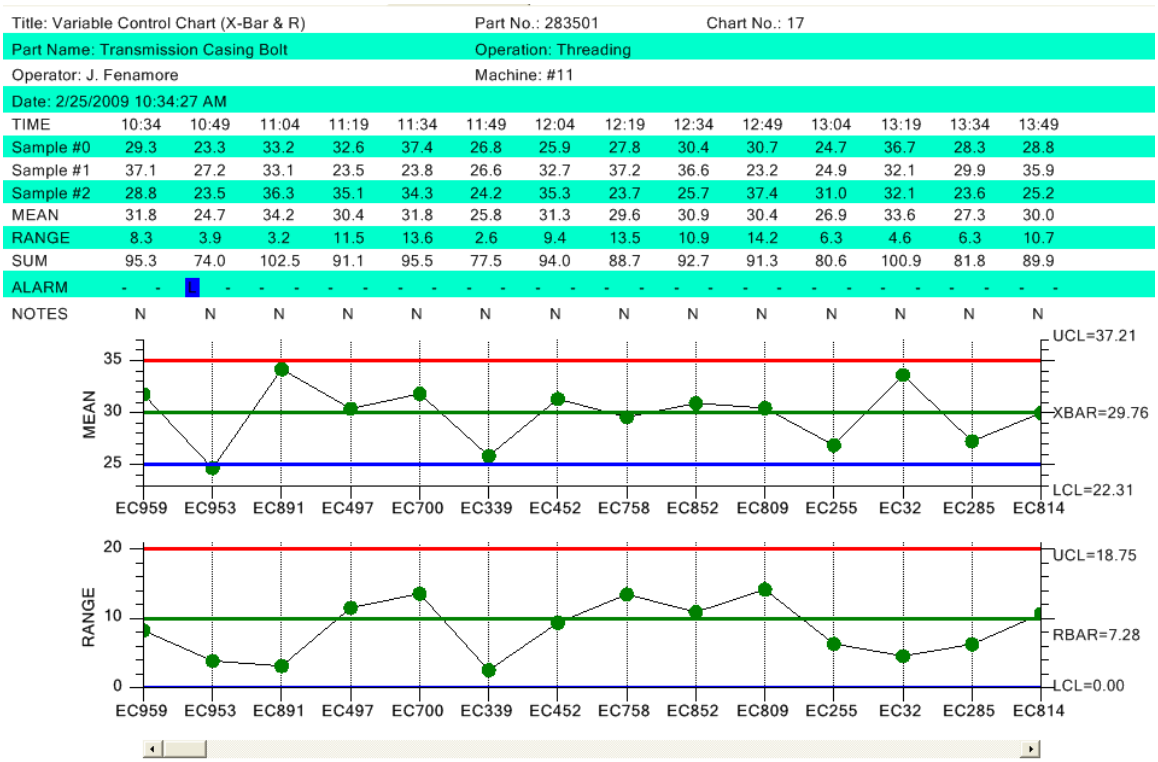
When updating the chart with sample data, use AddNewSampleRecord overload that has batch number and a time stamp parameters.

[C#]
```
this.ChartData.AddNewSampleRecord(batchCounter, timestamp, samples);
```

[VB]
```
Me.ChartData.AddNewSampleRecord(batchCounter, timestamp, samples)
```

See the example program BatchVariableControlCharts.BatchXBarRChart for a complete example. Reset the axis labeling mode back to batch number labeling by assigning the XAxisStringLabelMode property to SPCChartObjects.AXIS_LABEL_MODE_DEFAULT.

Batch Control Chart X-Axis User-Defined String Labeling



Batch X-Bar R Chart user-defined string labeling of the x-axis

Set the x-axis labeling mode using the overall charts XAxisStringLabelMode property, setting it `SPCChartObjects.AXIS_LABEL_MODE_STRING`.

[C#]

```
// enable scroll bar
this.EnableScrollBar = true;
this.EnableCategoryValues = false;

// Label the tick mark with user-defined strings
this.XAxisStringLabelMode = SPCChartObjects.AXIS_LABEL_MODE_STRING;
```

[VB]

```
' enable scroll bar
Me.EnableScrollBar = True
Me.EnableCategoryValues = False

' Label the tick mark with user-defined strings
Me.XAxisStringLabelMode = SPCChartObjects. AXIS_LABEL_MODE_STRING
```

Use the AddAxisUserDefinedString method to supply a new string for every new sample subgroup. It must be called every time the AddNewSampleRecord method is called, or the user-defined strings will get out of sync with their respective sample subgroup. Reset the axis labeling

mode back to batch number labeling by assigning the XAxisStringLabelMode property to SPCChartObjects.AXIS_LABEL_MODE_DEFAULT.

[C#]
```
this.ChartData.AddNewSampleRecord(batchCounter, timestamp, samples,
variableControlLimits);

// Make a random string to simulate some sort of batch sample group ID
int randomnum= (int) (1000 * ChartSupport.GetRandomDouble());
String batchidstring = "EC" + randomnum.ToString();
this.ChartData.AddAxisUserDefinedString(batchidstring);
```

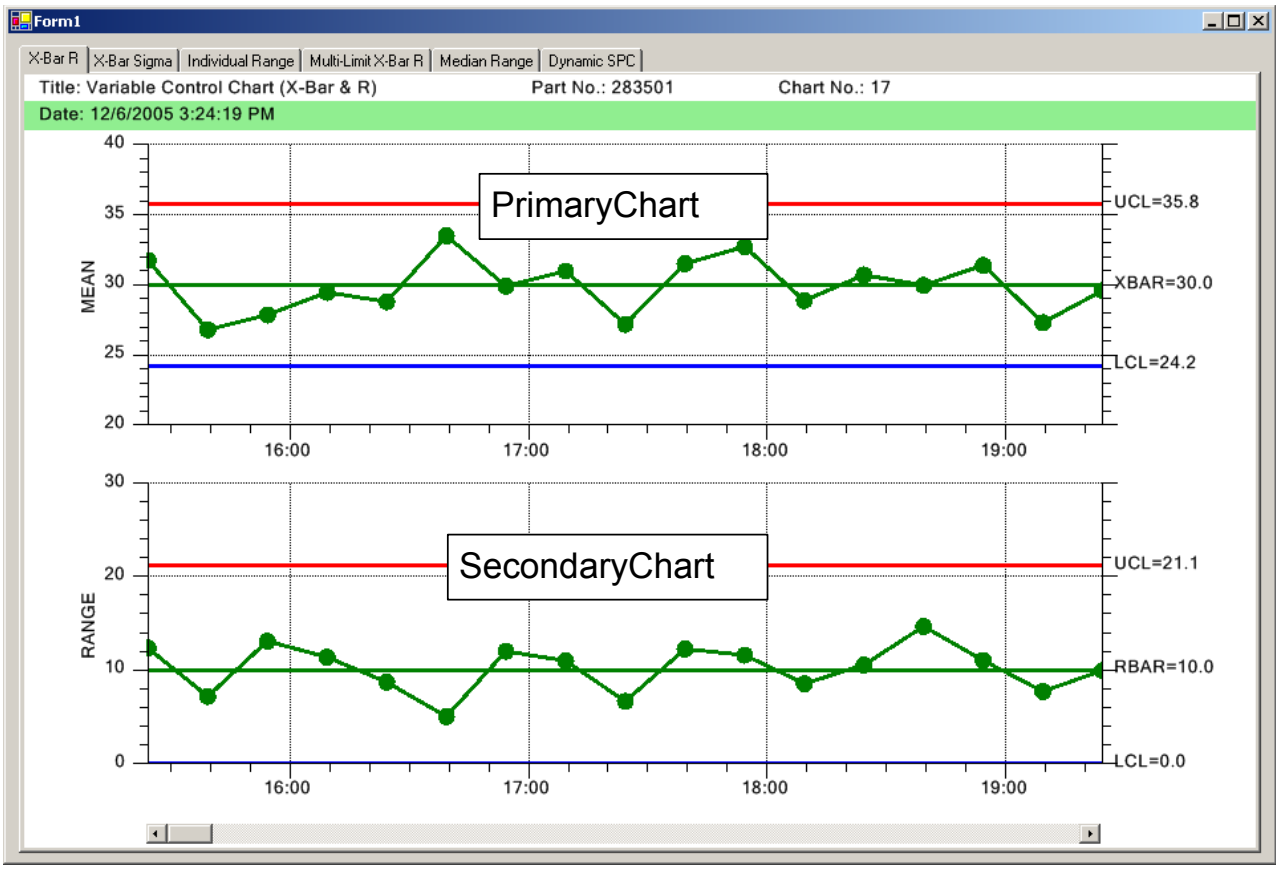
[VB]
```
Me.ChartData.AddNewSampleRecord(batchCounter, timestamp, samples, variableControlLimits)
Dim randomnum As Integer = CInt((1000 * ChartSupport.GetRandomDouble()))
Dim batchidstring As String = "EC" & randomnum.ToString()
Me.ChartData.AddAxisUserDefinedString(batchidstring)
```

See the example program BatchVariableControlCharts.VariableControlLimits for a complete example.

Changing Default Characteristics of the Chart

All *Variable Control Charts* have two distinct graphs, each with its own set of properties. The top graph is the Primary Chart, and the bottom graph is the Secondary Chart.

Logically enough, the properties of the objects that make up each of these graphs are stored in properties named **PrimaryChart** and **SecondaryChart**. Once the graph is initialized (using the **InitSPCTimeVariableControlChart**, or **InitSPCBatchVariableControlChart** method), you can modify the default characteristics of each graph using these properties.



[C#]

```
// Initialize the SPCTimeVariableControlChart
this.InitSPCTimeVariableControlChart(charttype,
       numsamplespersubgroup, numdatapointsinview, timeincrementminutes);
       .
```

```
        .
        .
this.PrimaryChart.XAxis.LineColor = Color.Blue;
this.PrimaryChart.XAxis.LineWidth = 3;

this.SecondaryChart.YAxis1.LineColor = Color.Green;
this.SecondaryChart.YAxis2.LineColor = Color.Red;
this.SecondaryChart.YAxis1.LineWidth = 3;
this.SecondaryChart.YAxis2.LineWidth = 3;

this.PrimaryChart.ProcessVariableData.LineMarkerPlot.LineAttributes.PrimaryColor =
Color.Black;
this.PrimaryChart.ProcessVariableData.LineMarkerPlot.SymbolAttributes.PrimaryColor =
Color.BlueViolet;
this.PrimaryChart.ProcessVariableData.LineMarkerPlot.SymbolAttributes.FillColor =
Color.Beige;
this.PrimaryChart.GraphBackground.FillColor = Color.LightGray;
this.PrimaryChart.PlotBackground.FillColor = Color.LightGoldenrodYellow;
```

[VB]

```
' Initialize the SPCTimeVariableControlChart
Me.InitSPCTimeVariableControlChart(charttype, numsamplespersubgroup, numdatapointsinview,
timeincrementminutes)
.
.
.
Me.PrimaryChart.XAxis.LineColor = Color.Blue
Me.PrimaryChart.XAxis.LineWidth = 3

Me.SecondaryChart.YAxis1.LineColor = Color.Green
Me.SecondaryChart.YAxis2.LineColor = Color.Red
Me.SecondaryChart.YAxis1.LineWidth = 3
Me.SecondaryChart.YAxis2.LineWidth = 3

Me.PrimaryChart.ProcessVariableData.LineMarkerPlot.LineAttributes.PrimaryColor =
Color.Black
Me.PrimaryChart.ProcessVariableData.LineMarkerPlot.SymbolAttributes.PrimaryColor =
Color.BlueViolet
Me.PrimaryChart.ProcessVariableData.LineMarkerPlot.SymbolAttributes.FillColor =
Color.Beige
Me.PrimaryChart.GraphBackground.FillColor = Color.LightGray
```

The **PrimaryChart** and **SecondaryChart** objects are both instances of the **SPCChartObjects** class. The **SPCChartObjects** class contains the objects needed to display a single graph. Below you will find a summary of the class properties.

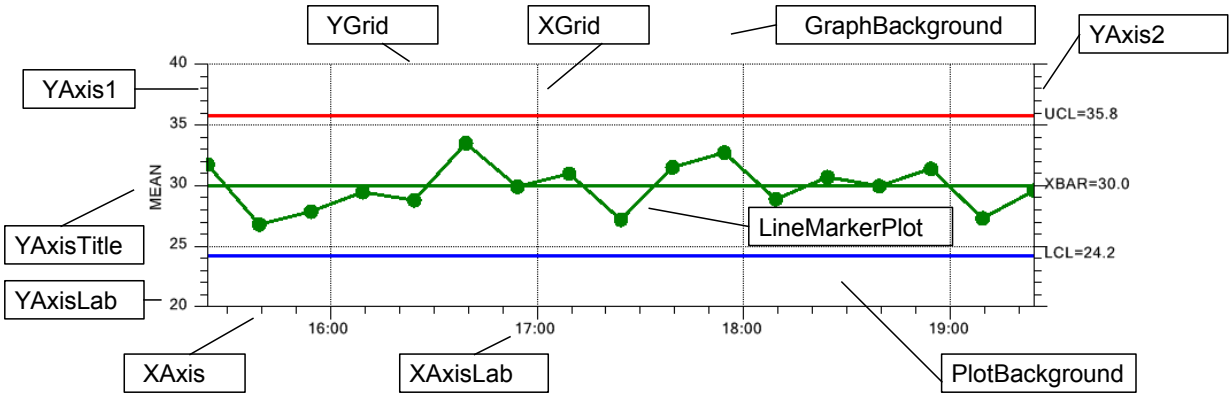
Public Instance Properties

AnnotationArray	Get the array of TextObject objects, representing the annotations of the chart.
AnnotationFont	Set/Get annotation font.
AnnotationNudge	Set/Get the x and y-values use to offset a data points annotation with respect to the actual data point.
AxisLabelFont	Set/Get the font used to label the x- and y- axes.
AxisTitleFont	Set/Get the font used for the axes titles.
ControlLabelPosition	Set/Get that numeric label for a control limit is

	placed inside, or outside the plot area INSIDE_PLOTAREA.
ControlLimitData	Get the array of the plot objects associated with control limits.
Datatooltip	Get a reference to the charts tooltip.
DefaultChartBackgroundColor	Get/Set the default background color for the graph area.
DefaultNumberControlLimits	Set/Get the number of control limits in the chart.
DefaultPlotBackgroundColor	Get/Set the default background color for the plot area.
DisplayChart	Set to true to enable the drawing of this chart.
DisplayFrequencyHistogram	Set to true to enable the drawing of the frequency histogram attached to the chart.
FrequencyHistogramChart	Get a reference to the optional frequency histogram attached to the chart.
GraphBackground	Get a reference to the charts graph background object.
BatchIncrement	Set/Get increment between adjacent samples of Batch type charts that use a numeric x-scale.
BatchStartValue	Set/Get the starting numeric value of the x-scale for Batch type charts that use a numeric x-scale.
BatchStopValue	Set/Get the ending numeric value of the x-scale for Batch type charts that use a numeric x-scale.
Header	Get a reference to the charts header.
HeaderFont	Set/Get the font used for the chart title.
HistogramStartPos	Set/Get the left edge, using normalized coordinates, of the frequency histogram plotting area.
HistogramOffset	Set/Get the offset with respect to the GraphStartPosX value, using normalized coordinates, of the frequency histogram plotting area.
MaxY	Set/Get the maximum value used to scale the y-axis of the chart.
MinY	Set/Get the minimum value used to scale the y-axis of the chart.
ParentSPCChartBase	Set/Get that parent SPCChartBase object.
PlotBackground	Get a reference to the charts plot background object.
PlotMeasurementValues	Set to true to enable the plotting of all sampled values, as a scatter plot, in addition to the mean or median values.
PPhysTransform1	Gets a reference to the charts physical

	coordinate system.
ProcessVariableData	Holds a reference to an object encapsulating the plot object data associated with the main variable of the chart.
SampledDataData	Get the array of the sample data.
SubHead	Get a reference to the charts subhead.
SubheadFont	Set/Get the font used for the chart subhead.
TableFont	Set/Get the font used for the data table.
TextTemplate	Get/Set the text template for the data tooltip.
TimeIncrementMinutes	Get/Set the increment between adjacent samples of charts that use a numeric x-scale.
ToolTipFont	Set/Get tooltip font.
ToolTipSymbol	Get a reference to the charts tooltip symbol.
XAxis	Get a reference to the charts x-axis.
XAxisLab	Get a reference to the charts x-axis labels.
XGrid	Get a reference to the charts x-axis grid.
XValueTemplate	Get/Set the x-value template for the data tooltip.
YAxis1	Get a reference to the charts left y-axis.
YAxis2	Get a reference to the charts right y-axis.
YAxisLab	Get a reference to the charts left y-axis labels.
YAxisTitle	Get a reference to the charts left y-axis title.
YGrid	Get a reference to the charts y-axis grid.
YValueTemplate	Get/Set the y-value template for the data tooltip.

The main objects of the graph are labeled in the graph below.


YGrid
XGrid
GraphBackground
YAxis2
YAxis1
UCL=35.8
XBAR=30.0
LCL=24.2
MEAN
YAxisTitle
LineMarkerPlot
YAxisLab
40
35
30
25
20
16:00
17:00
18:00
19:00
XAxis
XAxisLab
PlotBackground

7. SPC Attribute Control Charts

SPCTimeAttributeControlChart
SPCBatchAttributeControlChart

Attribute Control Charts are a set of control charts specifically designed for tracking product defects (also called non-conformities). These types of defects are binary in nature (yes/no), where a part has one or more defects, or it doesn't. Examples of defects are paint scratches, discolorations, breaks in the weave of a textile, dents, cuts, etc. Think of the last car that you bought. The defects in each sample group are counted and run through some statistical calculations. Depending on the type of *Attribute Control Chart*, the number of defective parts are tracked (p-chart and np-chart), or alternatively, the number of defects are tracked (u-chart, c-chart). The difference in terminology "number of defective parts" and "number of defects" is highly significant, since a single part not only can have multiple defect categories (scratch, color, dent, etc), it can also have multiple defects per category. A single part may have 0 – N defects. So keeping track of the number of defective parts is statistically different from keeping track of the number of defects. This affects the way the control limits for each chart are calculated.

p-Chart - Also known as the Percent or Fraction Defective Parts Chart
For a sample subgroup, the number of defective parts is measured and plotted as either a percentage of the total subgroup sample size, or a fraction of the total subgroup sample size. Since the plotted value is a fraction or percent of the sample subgroup size, the size of the sample group can vary without rendering the chart useless.

np-Chart – Also known as the Number Defective Parts Chart
For a sample subgroup, the number of defective parts is measured and plotted as a simple count. Statistically, in order to compare number of defective parts for one subgroup with the other subgroups, this type of chart requires that the subgroup sample size is fixed across all subgroups.

c-Chart - Also known as the Number of Defects or Number of Non-Conformities Chart
For a sample subgroup, the number of times a defect occurs is measured and plotted as a simple count. Statistically, in order to compare number of defects for one subgroup with the other subgroups, this type of chart requires that the subgroup sample size is fixed across all subgroups.

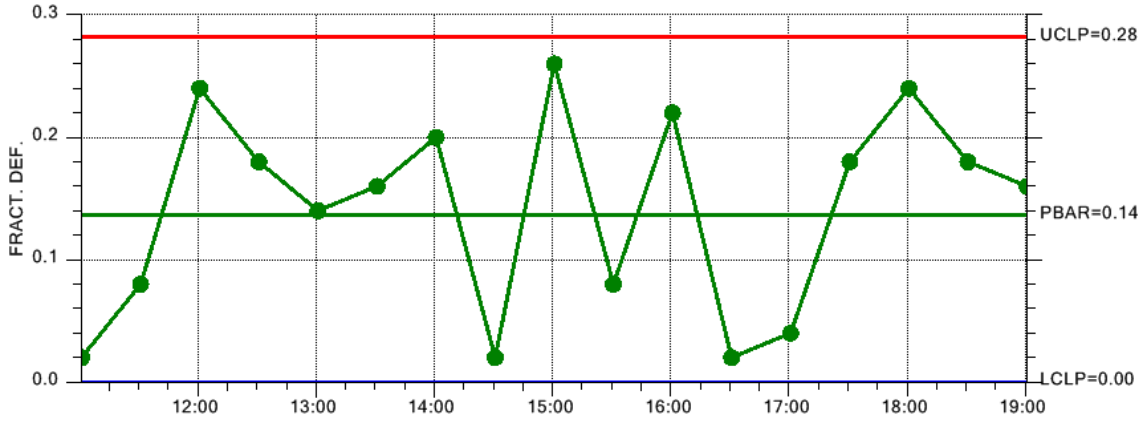
u-Chart – Also known as the Number of Defects per Unit or Number of Non-Conformities per Unit Chart
For a sample subgroup, the number of times a defect occurs is measured and plotted as either a percentage of the total subgroup sample size, or a fraction of the total subgroup sample size. Since the plotted value is a fraction or percent of the sample subgroup size, the size of the sample group can vary without rendering the chart useless.

DPMO Chart – Also known as the Number of Defects per Million Chart
For a sample subgroup, the number of times a defect occurs is measured and plotted as a value normalized to defects per million. Since the plotted value is normalized to a fixed sample subgroup size, the size of the sample group can vary without rendering the chart useless.

Time-Based and Batch-Based SPC Charts

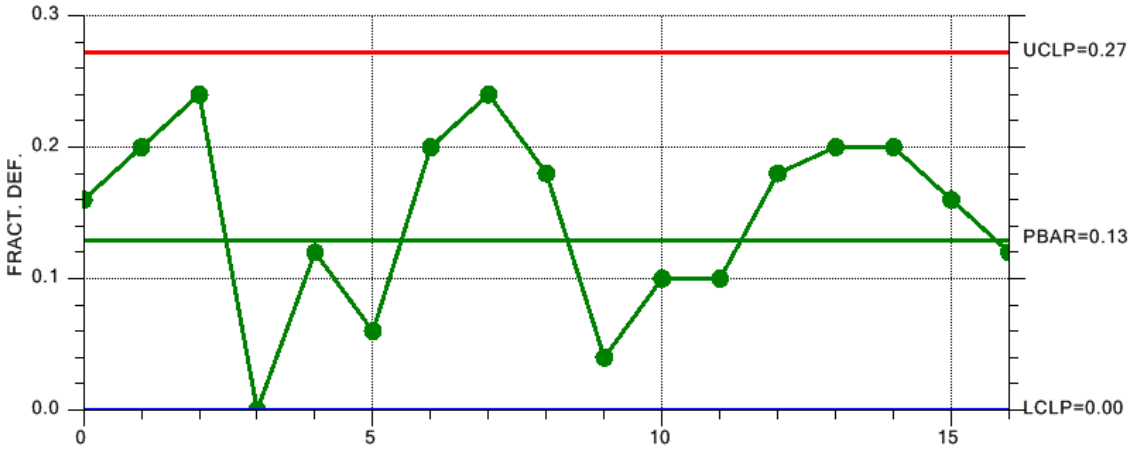
Attribute Control Charts are further categorized as either time- or batch- based. Use time-based SPC charts when data is collected using a subgroup interval corresponding to a specific time interval. Use batch-based SPC charts when the data subgroup interval is a sequential batch number that does not correspond to a uniform time interval. The major difference in these two types of SPC charts is the display of the x-axis. Control charts that sample using a uniform time interval will generally use a time-based x-axis, with time/date axis labels. Control charts that sample based on batches will generally use a numeric-based x-axis, with numeric axis labels.

Time-Based Attribute Control Chart



Note the time-based x-axis.

Batch-Based Attribute Control Chart



Note the numeric based x-axis.

Attribute Control Charts Consist of Only One Graph

Whereas the *Variable Control Charts* contain two different graphs, which we refer to generically as the primary and secondary graphs of the chart, *Attribute Control Charts* only have a single graph, which we refer to generically as the primary graph of the chart.

Creating an Attribute Control Chart

First, select whether you want to use a time-based attribute control chart (use **SPCTimeAttributeControlChart**) or a batch-based attribute control chart (use **SPCBatchAttributeControlChart**). Use that class as the base class for your chart. Since the two classes are very similar and share 95% of all properties in common, only the **SPCTimeAttributeControlChart** is discussed in detail, with the differences between the two classes discussed at the end of the chapter.

[C#]

```
public class FractionDefectivePartsControlChart :
    com.quinncurtis.spcchartnet.SPCTimeAttributeControlChart
{
    private System.ComponentModel.IContainer components;
    ChartCalendar startTime = new ChartCalendar();
    //  SPC attribute control chart type
    int charttype = SPCControlChartData.FRACTION_DEFECTIVE_PARTS_CHART;
    // Number of samples per sub group
    int numsamplespersubgroup = 50;
    // Number of defect categories
    int numcategories = 6;
    // Number of data points in the view
    int numdatapointsinview = 17;
    // The time increment between adjacent subgroups
    int timeincrementminutes = 30;

    public FractionDefectivePartsControlChart()
    {
        // This call is required by the Windows.Forms Form Designer.
        InitializeComponent();
        // Have the chart fill parent client area
        this.Dock = DockStyle.Fill;
        // Define and draw chart
        InitializeChart();
```

```
    }

    void InitializeChart ()
    {
        // Initialize the SPCTimeAttributeControlChart
        this.InitSPCTimeAttributeControlChart(charttype, numcategories,
            numsamplespersubgroup, numdatapointsinview, timeincrementminutes);
        .
        .
        .

        this.RebuildChartUsingCurrentData();

    }
}
```

[VB]

```
Public Class SimpleAttributeControlChart
    Inherits com.quinncurtis.spcchartnet.SPCTimeAttributeControlChart

#Region " Windows Form Designer generated code "

    Public Sub New()
        MyBase.New()
        'This call is required by the Windows Form Designer.
        InitializeComponent()
        'Add any initialization after the InitializeComponent() call
        ' Have the chart fill parent client area
        Me.Dock = DockStyle.Fill
        ' Define and draw chart
        InitializeChart ()
    End Sub
.
.
.

#End Region

Dim startTime As New ChartCalendar()
'  SPC attribute control chart type
Dim charttype As Integer = SPCControlChartData.FRACTION_DEFECTIVE_PARTS_CHART
' Number of samples per sub group
Dim numsamplespersubgroup As Integer = 50
' Number of defect categories
Dim numcategories As Integer = 5
' Number of data points in the view
 Dim numdatapointsinview As Integer = 17
 ' The time increment between adjacent subgroups
 Dim timeincrementminutes As Integer = 30

 Sub InitializeChart ()
        ' Initialize the SPCTimeAttributeControlChart
    Me.InitSPCTimeAttributeControlChart(charttype, numcategories, _
        numsamplespersubgroup, numdatapointsinview, timeincrementminutes)
    .
    .
    .
    Me.RebuildChartUsingCurrentData()
  End Sub 'DrawChart
    .
    .
    .
End Class
```

SPCTimeAttributeControlChart Members

SPCTimeAttributeControlChart overview

Public Instance Constructors

SPCTimeAttributeControlChart	Overloaded. Initializes a new instance of the SPCTimeAttributeControlChart class.

Public Instance Methods

InitSPCTimeAttributeControlChart	Overloaded. Initialize the class for a specific SPC chart type.

The control chart type (p-, np-, c- and u-charts) is established in the attribute control charts **InitSPCTimeAttributeControlChart** initialization routine.

SPCTimeAttributeControlChart.InitSPCTimeAttributeControlChart Method

This initialization method initializes the most important values in the creation of a SPC chart.

[VB]
```
Overloads Public Sub InitSPCTimeAttributeControlChart( _
   ByVal charttype As Integer, _
   ByVal numcategories As Integer, _
   ByVal numsamplespersubgroup As Integer, _
   ByVal numdatapointsinview As Integer, _
   ByVal timeincremenminutest As Integer _
)
```
[C#]
```
public void InitSPCTimeAttributeControlChart(
   int charttype,
   int numcategories,
   int numsamplespersubgroup,
   int numdatapointsinview,
   int timeincrementminutes
);
```

Parameters

charttype

Specifies the chart type. Use one of the SPC Attribute Control chart types: PERCENT_DEFECTIVE_PARTS_CHART, FRACTION_DEFECTIVE_PARTS_CHART, NUMBER_DEFECTIVE_PARTS_CHART, NUMBER_DEFECTS_PERUNIT_CHART, NUMBER_DEFECTS_CHART, NUMBER_DEFECTS_PER_MILLION_CHART.

numcategories

In Attribute Control Charts this value represents the number of defect categories used to determine defect counts.

numsamplespersubgroup

In an Attribute Control chart it represents the total sample size per sample subgroup from which the defect data is counted.

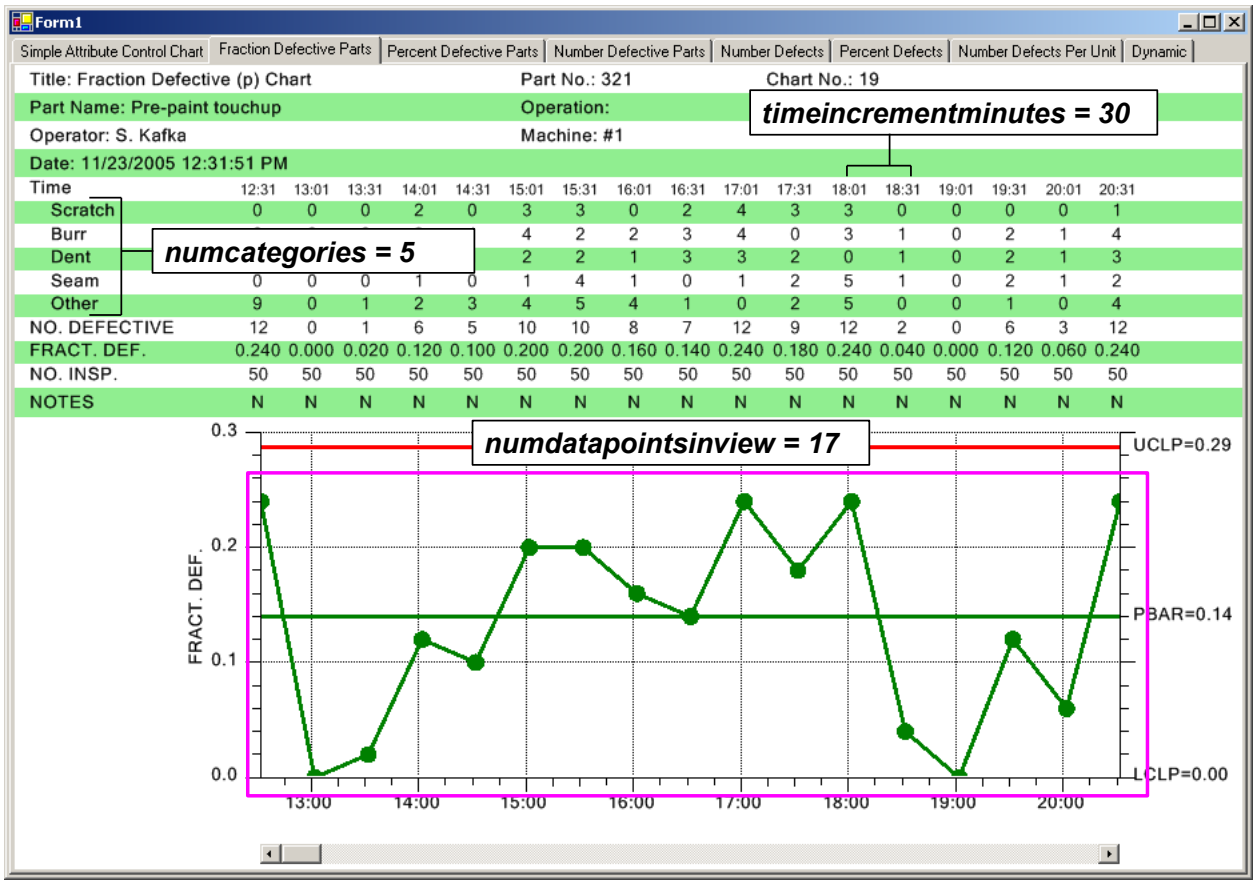
numdatapointsinview

Specifies the number of sample subgroups displayed in the graph at one time.

timeincremenminutes

Specifies the normal time increment between adjacent subgroup samples.

The image below further clarifies how these parameters affect the attribute control chart.



Time	12:31	13:01	13:31	14:01	14:31	15:01	15:31	16:01	16:31	17:01	17:31	18:01	18:31	19:01	19:31	20:01	20:31
Scratch	0	0	0	2	0	3	3	0	2	4	3	3	0	0	0	0	1
Burr						4	2	2	3	4	0	3	1	0	2	1	4
Dent						2	2	1	3	3	2	0	1	0	2	1	3
Seam	0	0	0	1	0	1	4	1	0	1	2	5	1	0	2	1	2
Other	9	0	1	2	3	4	5	4	1	0	2	5	0	0	1	0	4
NO. DEFECTIVE	12	0	1	6	5	10	10	8	7	12	9	12	2	0	6	3	12
FRACT. DEF.	0.240	0.000	0.020	0.120	0.100	0.200	0.200	0.160	0.140	0.240	0.180	0.240	0.040	0.000	0.120	0.060	0.240
NO. INSP.	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50
NOTES	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N

Once the Init routine is called, the chart can be further customized using properties inherited from **SPCBaseChart**, described below.

Public Static (Shared) Properties

DefaultChartFontString	Set/Get the default font used in the table display.

Public Instance Constructors

SPCChartBase	Overloaded. Initializes a new instance of the SPCChartBase class.

Public Instance Properties

AutoLogAlarmsAsNotes	Set to true to automatically log alarm details in the sample interval Notes record.

BottomLabelMargin	Get/Set an additional margin, in normalized coordinates, if only the primary graphs is displayed, allowing for the x-axis labels
ChartData	Get the object that holds the descriptive text, sampled and calculated values associated with the control chart.
ChartAlarmEmphasisMode	Set to SPCChartBaseALARM_HIGHLIGHT_SYMBOL to highlight the process variable symbol if an alarm condition exists. Set to Set to SPCChartBase.ALARM_NO_HIGHLIGHT_SYMBOL to turn off alarm highlighting.
ChartTable	Get the object that holds the data table information needed to display the data table along with the chart
DefaultControlLimitSigma	Set/Get that SPC control limits are to be calculated using the 3 sigma level standard.
EnableAlarmStatusValues	If set true enables the alarm status row of the chart table.
EnableCalculatedValues	If set true enables the calculated values rows of the data table
EnableCategoryValues	If set true enables the category or sample values rows of the data table
EnableDataToolTip	If set true enables data tooltips
EnableInputStringsDisplay	If set true enables the input string rows of the data table
EnableNotes	If set true enables the notes row of the data table
EnableNotesToolTip	If set true enables data tooltips
EnableScrollBar	If set true the scroll bar is added to the bottom of the chart.
EnableTimeValues	If set true enables the time row of the data table
EnableTotalSamplesValues	If set true enables the total of sampled values row of the data table
GraphBottomPos	Get/Set the bottom edge, using normalized coordinates, of the plotting area for the secondary chart
GraphStartPosX	Get/Set the left edge, using normalized coordinates, of the plotting area for both primary and secondary charts
GraphStartPosY1	Get the top edge, using normalized coordinates, of the plotting area for the primary chart
GraphStartPosY2	Get the top edge, using normalized coordinates, of the plotting area for the secondary chart
GraphStopPosX	Get/Set the right edge, using normalized coordinates, of the plotting area for both primary and secondary charts
GraphStopPosY1	Get the bottom edge, using normalized coordinates, of

	the plotting area for the primary chart
GraphStopPosY2	Get the bottom edge, using normalized coordinates, of the plotting area for the secondary chart
GraphTopTableOffset	Get/Set the offset of the top of the primary chart from the bottom of the data table, using normalized coordinates
HeaderStringsLevel	Set/Get the level of header strings to include in the chart. Use one of the SPCControlChartData header strings constants: HEADER_STRINGS_LEVEL0, HEADER_STRINGS_LEVEL1, HEADER_STRINGS_LEVEL2, or HEADER_STRINGS_LEVEL3
InterGraphMargin	Get/Set the margin, in normalized coordinates, between the primary and secondary charts
MultipleMouseListener	Set/Get the MultiMouseListener.
PrimaryChart	Get the object that holds he the chart objects needed to display the primary chart
ScrollBarBottomPosition	Get/Set the bottom edge, using normalized coordinates, of the optional scroll bar
ScrollBarPixelHeight	Get/Set the height of the scrollbar in pixels
SecondaryChart	Get the object that holds he the chart objects needed to display the secondary chart
SPCChartType	Specifies the control chart type: use one of the SPCControlChartData chart type constants: MEAN_RANGE_CHART, MEDIAN_RANGE_CHART, MEAN_SIGMA_CHART, MEAN_SIGMA_CHART_VSS, INDIVIDUAL_RANGE_CHART, CUSTOM_ATTRIBUTE_CONTROL_CHART, PERCENT_DEFECTIVE_PARTS_CHART, FRACTION_DEFECTIVE_PARTS_CHART, NUMBER_DEFECTIVE_PARTS_CHART, NUMBER_DEFECTS_CHART, NUMBER_DEFECTS_PERUNIT_CHART, NUMBER_DEFECTS_PER_MILLION_CHART.
TableAlarmEmphasisMode	Set the table alarm highlighting to one of the SPCChartBase table highlight constants: ALARM_HIGHLIGHT_NONE, ALARM_HIGHLIGHT_TEXT, ALARM_HIGHLIGHT_OUTLINE, ALARM_HIGHLIGHT_BAR
XScaleMode	Set/Get whether the x-axis is time based, or numeric

based.

Public Instance Methods

AddAnnotation	Overloaded. Add a simple annotation to a data point in the specified SPC chart.
AutoCalculateControlLimits	Using the current sampled data values, high, target and low control limits are calculated for both primary and secondary charts using an algorithm appropriate to the SPC chart type.
AutoCalculatePrimaryControlLimits	Using the current sampled data values, high, target and low control limits are calculated for the primary chart using an algorithm appropriate to the SPC chart type.
AutoCalculateSecondaryControlLimits	Using the current sampled data values, high, target and low control limits are calculated for the primary chart using an algorithm appropriate to the SPC chart type.
AutoScaleChartYRange	Auto-scale the y-range of the SPC chart so that all of the sampled data and chart control limits are within the bounds of the y-axis.
AutoScalePrimaryChartYRange	Auto-scale the y-range of the primary SPC chart so that all of the sampled data and chart control limits are within the bounds of the y-axis.
AutoScaleSecondaryChartYRange	Auto-scale the y-range of the SPC chart so that all of the sampled data and chart control limits are within the bounds of the y-axis.
Copy	Overloaded. Copies the source object.
Draw	Overrides the Draw method of the underlying ChartView class, so that the scroll bar can be properly repositioned if the size of the window changes. The graphics context the chart is drawn to.
InitSPCChartBase	This initialization method initializes the most important values in the creation of a SPC chart.
IsTimeScale	Returns true if the coordinate system has a time based x-axis. The coordinate system of the chart.
MakeControlLinePlot	Draw a control line, either a simple straight line, or a variable control line, for the specified chart.
RebuildChartUsingCurrentData	Rebuild the graph taking into account the most recent data values.

RescaleGraphsToScrollbar	Rescale primary and secondary charts based on the position of the value of the scroll bar. The thumb position of the scroll bar.
ResetSPCChartData	Reset the history buffers of all of the SPC data objects.
UpdateControlLimitLabel	Creates a numeric label of the control limit, and adds the numeric label to the spc chart.

Special Note for DPMO Charts

The NUMBER_DEFECTS_PER_MILLION_CHART has an important parameter you may need to set. DPMO charts use an important parameter known is the *defect opportunites per unit*. The default value for the parameter is 1. So if you are using 1 as the the value of *defect opportunites per unit* in your chart, you don't need to do anything. If your value is greater than 1, you need to specify that using code similar to below.

```
C#          this.ChartData.DefectOpportunitiesPerUnit = 5;

VB           Me.ChartData.DefectOpportunitiesPerUnit = 5
```

Adding New Sample Records for Attribute Control Charts.

Attribute Control Chart Cross Reference

p-chart = FRACTION_DEFECTIVE_PARTS_CHART
or
PERCENT_DEFECTIVE_PARTS_CHART

np-chart = NUMBER_DEFECTIVE_PARTS_CHART

c-chart = NUMBER_DEFECTS_CHART

u-chart = NUMBER_DEFECTS_PERUNIT_CHART

DPMO = NUMBER_DEFECTS_PER_MILLION_CHART

Updating p- and np-charts

In attribute control charts, the meaning of the data in the *samples* array varies, depending on whether the attribute control chart measures the number of defective parts (p-, and np-charts), or the total number of defects (u- and c-charts). The major anomaly is that while the p- and np-charts plot the fraction or number of defective parts, the table portion of the chart can display defect counts for any number of defect categories (i.e. paint scratches, dents, burrs, etc.). It is critical to understand that total number of defects, i.e. the sum of the items in the defect categories for a give sample subgroup, do NOT have to add up to

the number of defective parts for the sample subgroup. Every defective part not only can have one or more defects, it can have multiple defects of the same defect category. The total number of defects for a sample subgroup will always be equal to or greater than the number of defective parts. When using p- and np-charts that display defect category counts as part of the table, where N is the *numcategories* parameter in the **InitSPCTimeAttributeControlChart** or **InitSPCBatchAttributeControlChart** initialization call, the first N elements of the *samples* array holds the defect count for each category. The N+1 element of the *samples* array holds the total defective parts count. For example, if you initialized the chart with a *numcategories* parameter to five, signifying that you had five defect categories, you would use a *samples* array sized to six, as in the code below:

[C#]

```
DoubleArray samples = new DoubleArray(6);
//  ChartCalendar initialized with current  time by default
ChartCalendar timestamp = new ChartCalendar();
// Place sample values in array
samples[0] = 3;     // Number of defects for defect category #1
samples[1] = 0;     // Number of defects for defect category #2
samples[2] = 4;     // Number of defects for defect category #3
samples[3] = 2;     // Number of defects for defect category #4
samples[4] = 3;     // Number of defects for defect category #5

samples[5] = 4;    // TOTAL number of defective parts in the sample

// Add the new sample subgroup to the chart
this.ChartData.AddNewSampleRecord(timestamp, samples);
```

[VB]

```
Dim samples As DoubleArray = New DoubleArray(6)
'  ChartCalendar initialized with current  time by default
Dim timestamp As ChartCalendar = New ChartCalendar()
' Place sample values in array
samples(0) = 3      ' Number of defects for defect category #1
samples(1) = 0      ' Number of defects for defect category #2
samples(2) = 4      ' Number of defects for defect category #3
samples(3) = 2      ' Number of defects for defect category #4
samples(4) = 3      ' Number of defects for defect category #5

samples(5) = 4     ' TOTAL number of defective parts in the sample

' Add the new sample subgroup to the chart
 Me.ChartData.AddNewSampleRecord(timestamp, samples)
```

This is obscured in our example programs a bit because we use a special method to simulate defect data for n- and np-charts. The code below is extracted from our TimeAttributeControlCharts.NumberDefectivePartsControlChart example program.

[C#]

```
DoubleArray samples = this.ChartData.SimulateDefectRecord(50 * 0.134,
       SPCControlChartData.NUMBER_DEFECTIVE_PARTS_CHART);
// Add new sample record
this.ChartData.AddNewSampleRecord( timestamp, samples);
```

[VB]

```
Dim samples As DoubleArray = Me.ChartData.SimulateDefectRecord(50 * 0.134, _
    SPCControlChartData.NUMBER_DEFECTIVE_PARTS_CHART)
' Add new sample record
Me.ChartData.AddNewSampleRecord(timestamp, samples)
```

This particular overload for **ChartData.SimulateDefectRecord** knows that since it is a NUMBER_DEFECTIVE_PARTS_CHART chart (np-chart), and that since the **ChartData** object was setup with five categories in the **InitSPCTimeAttributeControlChart** call, that is should return a **DoubleArray** with (5 + 1 = 6) elements, the first five elements representing simulated defect counts for the five defect categories, and the sixth element the simulated defective parts count. The defect category count data of the *samples* array is only used in the table part of the display; the defect category counts play NO role in the actual SPC chart. The only value that is used in plotting the SPC chart is the last element in the *samples* array, the defective parts count for the sample subgroup.

Updating c- and u-charts

In c- and u-charts the number of defective parts is of no consequence. The only thing that is tracked is the number of defects. Therefore, there is no extra array element tacked onto the end of the *samples* array. Each element of the *samples* array corresponds to the total number of defects for a given defect category. If the *numcategories* parameter in the **InitSPCTimeAttributeControlChart** or **InitSPCBatchAttributeControlChart** is initialized to five, the total number of elements in the *samples* array should be five. For example:

[C#]

```
DoubleArray samples = new DoubleArray(5);
//  ChartCalendar initialized with current  time by default
ChartCalendar timestamp = new ChartCalendar();
// Place sample values in array
samples[0] = 3;     // Number of defects for defect category #1
samples[1] = 0;     // Number of defects for defect category #2
samples[2] = 4;     // Number of defects for defect category #3
samples[3] = 2;     // Number of defects for defect category #4
samples[4] = 3;     // Number of defects for defect category #5

// Add the new sample subgroup to the chart
this.ChartData.AddNewSampleRecord(timestamp, samples);
```

[VB]

```
Dim samples As DoubleArray = New DoubleArray(5)
'  ChartCalendar initialized with current  time by default
Dim timestamp As ChartCalendar = New ChartCalendar()
' Place sample values in array
samples(0) = 3      ' Number of defects for defect category #1
samples(1) = 0      ' Number of defects for defect category #2
samples(2) = 4      ' Number of defects for defect category #3
samples(3) = 2      ' Number of defects for defect category #4
samples(4) = 3      ' Number of defects for defect category #5
```

```
' Add the new sample subgroup to the chart
 Me.ChartData.AddNewSampleRecord(timestamp, samples)
```

While the table portion of the display can display defect data broken down into categories, only the sum of the defects for a given sample subgroup is used in creating the actual SPC chart. Note that the code below, extracted from the TimeAttributeControlCharts.NumberDefectsControlChart example, uses a different **ChartData.SimulateDefectRecord** method to simulate the defect data.

Chart Header Information, Measured Data and Calculated Value Table

Standard worksheets used to gather and plot SPC data consist of three main parts.

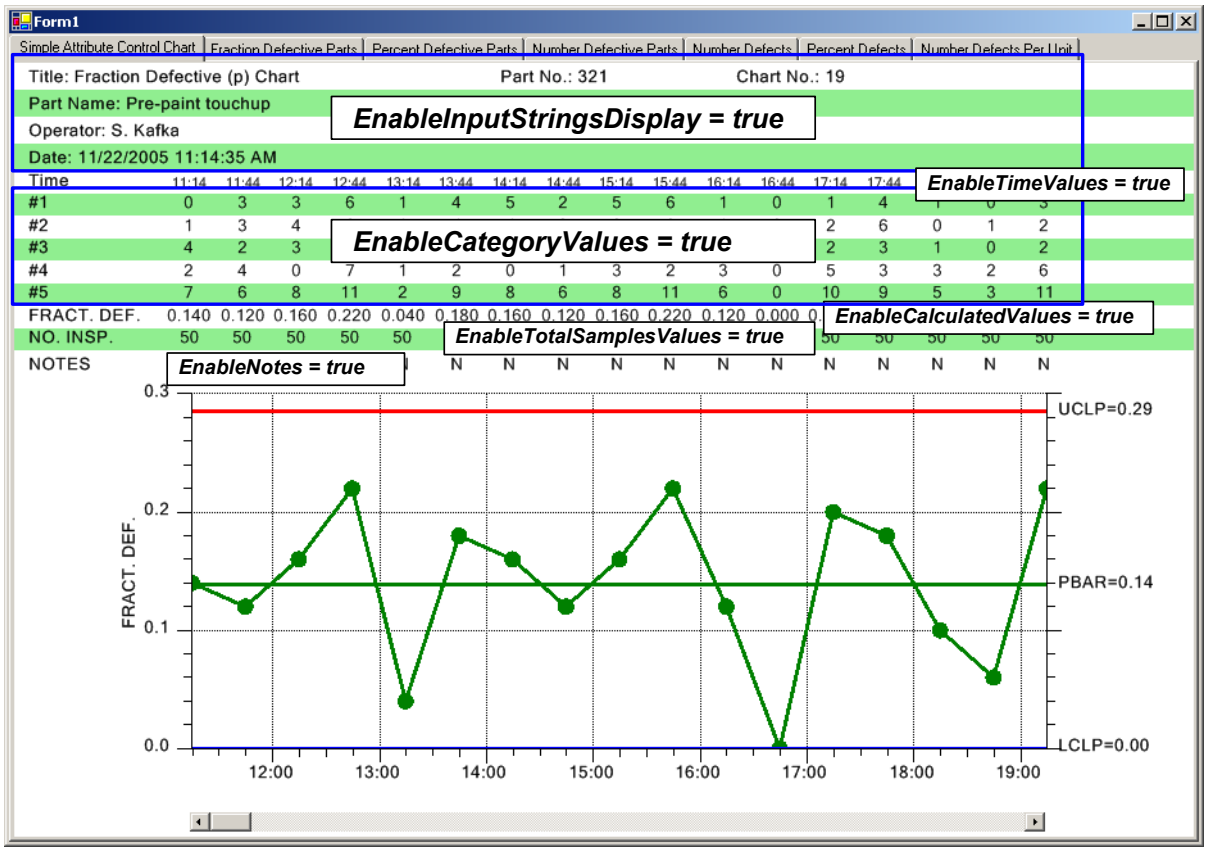
- The first part is the header section, identifying the title of the chart, the monitored process, the machine operator, part number and other important information specific to the chart.
- The second part is the measurement data recording and calculation section, organized as a table recording the sample data and calculated values in a neat, readable fashion.
- The third part plots the calculated SPC values as a SPC chart.

The chart includes options that enable the programmer to customize and automatically include header information along with a table of the measurement and calculated data, in the SPC chart.

The following properties enable sections of the chart header and table:

EnableInputStringsDisplay
EnableCategoryValues
EnableCalculatedValues
EnableTotalSamplesValues
EnableNotes
EnableTimeValues

The example code below is extracted from the **TimeAttributeControlCharts.SimpleAttributeControlChart** example program.



[C#]

```
void InitializeChart()
{
    // Initialize the SPCTimeAttributeControlChart
    this.InitSPCTimeAttributeControlChart(charttype, numcategories,
        numsamplespersubgroup, numdatapointsinview, timeincrementminutes);

    // Set the strings used in the header section of the table
    this.ChartData.Title = "Fraction Defective (p) Chart";
    this.ChartData.PartNumber = "321";
    this.ChartData.ChartNumber="19";
    this.ChartData.PartName= "Pre-paint touchup";
    this.ChartData.TheOperator="S. Kafka";

    // Display the Sampled value rows of the table
    this.EnableInputStringsDisplay= true;
    // Display the Sampled value rows of the table
    this.EnableCategoryValues= true;
    // Display the Calculated value rows of the table
    this.EnableCalculatedValues= true;
    // Display the total samples per subgroup value row
    this.EnableTotalSamplesValues= true;
    // Display the Notes row of the table
    this.EnableNotes= true;
    // Display the time stamp row of the table
    this.EnableTimeValues = true;
    .
    .
    .
    this.RebuildChartUsingCurrentData();
}
```

[VB]

```
Sub InitializeChart()
   ' Initialize the SPCTimeAttributeControlChart
   Me.InitSPCTimeAttributeControlChart(charttype, numcategories, _
       numsamplespersubgroup, numdatapointsinview, timeincrementminutes)

   ' Set the strings used in the header section of the table
   Me.ChartData.Title = "Fraction Defective (p) Chart"
   Me.ChartData.PartNumber = "321"
   Me.ChartData.ChartNumber = "19"
   Me.ChartData.PartName = "Pre-paint touchup"
   Me.ChartData.TheOperator = "S. Kafka"

   ' Display the Sampled value rows of the table
   Me.EnableInputStringsDisplay = True
   ' Display the Sampled value rows of the table
   Me.EnableCategoryValues = True
   ' Display the Calculated value rows of the table
   Me.EnableCalculatedValues = True
   ' Display the total samples per subgroup value row
   Me.EnableTotalSamplesValues = True
   ' Display the Notes row of the table
   Me.EnableNotes = True
   ' Display the time stamp row of the table
   Me.EnableTimeValues = True

   Me.RebuildChartUsingCurrentData()
End Sub 'InitializeChart
```

The input header strings display has four sub-levels that display increasing levels of information. The input header strings display level is set using the charts HeaderStringsLevel property. Strings that can be displayed are: Title, PartNumber, ChartNumber, DateString, PartName, Operation, Machine, SpecificationLimits, Gage, UnitOfMeasure, ZeroEquals and DateString. The four levels and the information displayed is listed below:

HEADER_STRINGS_LEVEL0	Display no header information
HEADER_STRINGS_LEVEL1	Display minimal header information: Title, PartNumber, ChartNumber, DateString
HEADER_STRINGS_LEVEL2	Display most header strings: Title, PartNumber, ChartNumber, PartName, Operation, Operator, Machine, DateString
HEADER_STRINGS_LEVEL3	Display all header strings: Title, PartNumber, ChartNumber, DateString, PartName, Operation, Machine, SpecificationLimits, Gage, UnitOfMeasure, ZeroEquals and DateString

The example program TimeAttributeControlCharts.SimpleAttributeControlChart demonstrates the use of the **HeaderStringsLevel** property. The example below displays a minimum set of header strings (HeaderStringsLevel = SPCControlChartData.HEADER_STRINGS_LEVEL1).

[C#]
```
// Set the strings used in the header section of the table
this.ChartData.Title = "Fraction Defective (p) Chart";
this.ChartData.PartNumber = "321";
this.ChartData.ChartNumber="19";
this.ChartData.DateString = DateTime.Now.ToString();
this.HeaderStringsLevel = SPCControlChartData.HEADER_STRINGS_LEVEL1;
```

[VB]
```
' Set the strings used in the header section of the table
Me.ChartData.Title = "Fraction Defective (p) Chart"
Me.ChartData.PartNumber = "321"
Me.ChartData.ChartNumber = "19"
Me.ChartData.DateString = DateTime.Now.ToString()
Me.HeaderStringsLevel = SPCControlChartData.HEADER_STRINGS_LEVEL1
```

The example below displays a maximum set of header strings (HeaderStringsLevel = SPCControlChartData.HEADER_STRINGS_LEVEL3).

Title: Fraction Defective (p) Chart	Part No.: 321	Chart No.: 19	
Part Name: Left Front Fender	Operation: Painting	Spec. Limits:	Units:
Operator: B. Cornwall	Machine: #11	Gage:	Zero Equals:
Date: 12/21/2005 11:48:39 AM			

[C#]
```
// Set the strings used in the header section of the table
this.ChartData.Title = "Fraction Defective (p) Chart";
this.ChartData.PartNumber = "283501";
this.ChartData.ChartNumber="17";
this.ChartData.TheOperator="B. Cornwall";
this.ChartData.PartName= "Left Front Fender";
this.ChartData.Operation = "Painting";
this.ChartData.SpecificationLimits="";
this.ChartData.Machine="#11";
this.ChartData.Gage="";
this.ChartData.UnitOfMeasure = "";
this.ChartData.ZeroEquals="";
this.ChartData.DateString = DateTime.Now.ToString();
this.HeaderStringsLevel = SPCControlChartData.HEADER_STRINGS_LEVEL3;
```

[VB]
```
' Set the strings used in the header section of the table
Me.ChartData.Title = "Fraction Defective (p) Chart"
Me.ChartData.PartNumber = "283501"
Me.ChartData.ChartNumber = "17"
Me.ChartData.TheOperator = "B. Cornwall"
Me.ChartData.PartName = "Left Front Fender"
Me.ChartData.Operation = "Painting"
Me.ChartData.SpecificationLimits = ""
Me.ChartData.Machine = "#11"
Me.ChartData.Gage = ""
Me.ChartData.UnitOfMeasure = ""
Me.ChartData.ZeroEquals = ""
Me.ChartData.DateString = DateTime.Now.ToString()
Me.HeaderStringsLevel = SPCControlChartData.HEADER_STRINGS_LEVEL3
```

The identifying string displayed in front of the input header string can be any string that you want, including non-English language string. For example, if you want the input header string for the Title to represent a project name:

Project Name: Project XKYZ for PerQuet

Set the properties:

[C#]
```
this.ChartData.Title = "Project XKYZ for PerQuet";
this.ChartData.TitleHeader = "Project Name:";
```

[VB]
```
Me.ChartData.Title = "Project XKYZ for PerQuet"
Me.ChartData.TitleHeader = "Project Name:"
```

Change other headers using the ChartData properties listed below.

- TitleHeader
- PartNumberHeader
- ChartNumberHeader
- PartNameHeader
- OperationHeader
- OperatorHeader
- MachineHeader
- DateHeader
- SpecificationLimitsHeader
- GageHeader
- UnitOfMeasureHeader
- ZeroEqualsHeader
- NotesHeader

Even though the input header string properties have names like Title, PartNumber, ChartNumber, etc., those names are arbitrary. They are really just placeholders for the strings that are placed at the respective position in the table. You can display any combination of strings that you want, rather than the ones we have selected by default, based on commonly used standardized SPC Control Charts.

Depending on the control chart type, you may want to customize the category header strings. In most of our examples, we use the category header strings: Scratch, Burr, Dent, Seam, and Other, to represent common defect categories. You can change these strings to anything that you want using the **ChartData.SetSampleRowHeaderString** method. See the example program TimeAttributeControlCharts.NumberDefectsControlChart.

Title: Number Defective per Unit (u) Chart						Part
Part Name: Pre-paint touchup						Ope
Operator: S. Kafka						Mac
Date: 12/21/2005 12:01:18 PM						
Time	12:01	12:31	13:01	13:31	14:01	14:31
Scratch	1	2	2	3	3	2
Burr	3	2	1	0	3	2
Dent	1	3	3	1	2	0
Seam	3	1	2	2	4	2
Other	4	3	0	1	1	3

[C#]

```
// Set the table row headers strings for defect categories
this.ChartData.SetSampleRowHeaderString(0, "    Scratch");
this.ChartData.SetSampleRowHeaderString(1, "    Burr");
this.ChartData.SetSampleRowHeaderString(2, "    Dent");
this.ChartData.SetSampleRowHeaderString(3, "    Seam");
this.ChartData.SetSampleRowHeaderString(4, "    Other");
```

[VB]

```
' Set the table row headers strings for defect categories
Me.ChartData.SetSampleRowHeaderString(0, "    Scratch")
Me.ChartData.SetSampleRowHeaderString(1, "    Burr")
Me.ChartData.SetSampleRowHeaderString(2, "    Dent")
Me.ChartData.SetSampleRowHeaderString(3, "    Seam")
Me.ChartData.SetSampleRowHeaderString(4, "    Other")
```

The **ChartTable** property of the chart has properties that further customize the chart. The default table background uses the accounting style green-bar striped background. You can change this using the **ChartTable.TableBackgroundMode** property**.** Set the value to one of the TableBackgroundMode constants:

TABLE_NO_COLOR_BACKGROUND	Constant specifies that the table does not use a background color.
TABLE_SINGLE_COLOR_BACKGROUND	Constant specifies that the table uses a single color for the background (backgroundColor1)
TABLE_STRIPED_COLOR_BACKGROUND	Constant specifies that the table uses horizontal stripes of color for the background (backgroundColor1 and backgroundColor2)
TABLE_SINGLE_COLOR_BACKGROUND_GRIDCELL	Constant specifies that the table uses a grid background, with backgroundColor1 the overall

background color and backgroundColor2
the color of the grid lines.

Extracted from the TimeAttributeControlCharts.PercentDefectivePartsControlChart example program

Title: Fraction Defective (p) Chart						Part No.: 321						Chart No.: 19					
Part Name: Pre-paint touchup						Operation:											
Operator: S. Kafka						Machine:											
Date: 12/21/2005 2:55:24 PM																	
Time	14:55	15:25	15:55	16:25	16:55	17:25	17:55	18:25	18:55	19:25	19:55	20:25	20:55	21:25	21:55	22:25	22:55
Scratch	2	6	1	0	0	1	1	1	5	2	1	0	3	1	0	0	5
Burr	3	7	2	1	3	2	1	6	5	6	2	2	2	0	1	1	2
Dent	2	2	0	0	7	1	1	4	5	5	2	2	2	1	6	1	7
Seam	1	6	4	1	2	2	1	2	0	5	1	0	2	1	5	0	2
Other	5	12	7	2	12	4	3	9	10	11	6	4	6	2	12	2	13
% DEF.	10.0	24.0	14.0	4.0	24.0	8.0	6.0	18.0	20.0	22.0	12.0	8.0	12.0	4.0	24.0	4.0	26.0
NO. INSP.	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50
NOTES	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N

[C#]

```
this.ChartTable.TableBackgroundMode =
    SPCGeneralizedTableDisplay.TABLE_STRIPED_COLOR_BACKGROUND;
this.ChartTable.BackgroundColor1 = Color.Bisque;
this.ChartTable.BackgroundColor2 = Color.LightGoldenrodYellow;
```

[VB]

```
Me.ChartTable.TableBackgroundMode = _
    SPCGeneralizedTableDisplay.TABLE_STRIPED_COLOR_BACKGROUND
Me.ChartTable.BackgroundColor1 = Color.Bisque
Me.ChartTable.BackgroundColor2 = Color.LightGoldenrodYellow
```

Extracted from the TimeAttributeControlCharts.NumberDefectivePartsControlChart example program

Title: Number Defective (np) Chart						Part No.: 321						Chart No.: 19					
Part Name: Pre-paint touchup						Operation:											
Operator: S. Kafka						Machine:											
Date: 12/21/2005 2:57:56 PM																	
Time	14:57	15:27	15:57	16:27	16:57	17:27	17:57	18:27	18:57	19:27	19:57	20:27	20:57	21:27	21:57	22:27	22:57
Scratch	6	6	6	1	1	3	5	4	1	6	9	5	4	2	6	4	8
Burr	3	4	1	9	1	2	4	5	6	5	4	2	4	1	6	5	3
Dent	5	9	4	5	1	10	0	3	6	9	5	10	1	2	5	8	3
Seam	7	6	1	3	5	9	3	0	3	7	6	8	8	9	7	3	9
Other	4	2	9	4	9	8	2	6	2	0	4	1	7	5	3	3	9
FRACT. DEF.	0.080	0.040	0.180	0.080	0.180	0.160	0.040	0.120	0.040	0.000	0.080	0.020	0.140	0.100	0.060	0.060	0.180
NO. INSP.	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50
NOTES	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N

[C#]

```
this.ChartTable.TableBackgroundMode =
    SPCGeneralizedTableDisplay.TABLE_SINGLE_COLOR_BACKGROUND;
this.ChartTable.BackgroundColor1 = Color.LightBlue;
```

[VB]

```
Me.ChartTable.TableBackgroundMode = _
    SPCGeneralizedTableDisplay.TABLE_SINGLE_COLOR_BACKGROUND
Me.ChartTable.BackgroundColor1 = Color.LightBlue
```

Extracted from the TimeAttributeControlCharts.NumberDefectivePartsControlChart example program

Title: Fraction Defective (p) Chart | Part No.: 321 | Chart No.: 19
Part Name: Pre-paint touchup | Operation:
Operator: S. Kafka | Machine:
Date: 12/21/2005 3:01:47 PM

Time	15:01	15:31	16:01	16:31	17:01	17:31	18:01	18:31	19:01	19:31	20:01	20:31	21:01	21:31	22:01	22:31	23:01
Scratch	1	4	0	0	0	0	1	0	1	0	0	2	1	0	1	2	3
Burr	2	3	0	0	0	0	4	0	1	1	0	3	2	0	0	4	5
Dent	4	5	0	3	1	0	0	0	1	1	0	4	2	1	1	0	4
Seam	4	5	0	2	1	0	2	0	1	1	0	1	2	1	1	0	2
Other	1	1	1	2	1	0	5	1	1	1	1	1	0	0	2	4	2
NO. DEFECTIVE	12	12	1	6	3	0	12	1	2	4	1	9	6	2	4	10	11
% DEF.	24.0	24.0	2.0	12.0	6.0	0.0	24.0	2.0	4.0	8.0	2.0	18.0	12.0	4.0	8.0	20.0	22.0
NO. INSP.	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50
NOTES	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N

[C#]
```
this.ChartTable.TableBackgroundMode =
       SPCGeneralizedTableDisplay.TABLE_NO_COLOR_BACKGROUND;
```

[VB]
```
Me.ChartTable.TableBackgroundMode = _
    SPCGeneralizedTableDisplay.TABLE_NO_COLOR_BACKGROUND
```

Title: Variable Control Chart (X-Bar & R) | Part No.: 283501 | Chart No.: 17
Part Name: Transmission Casing Bolt | Operation: Threading | Spec. Limits: | Units: 0.0001 inch
Operator: J. Fenamore | Machine: #11 | Gage: #8645 | Zero Equals: zero
Date: 4/15/2008 4:53:41 PM

TIME	16:53	17:08	17:23	17:38	17:53	18:08	18:23	18:38	18:53	19:08	19:23	19:38	19:53	20:08	20:23	20:38	20:53
MEAN	29.7	30.6	31.5	30.3	31.1	28.6	28.8	29.4	28.9	31.0	29.0	28.1	32.8	30.2	29.5	30.3	32.5
RANGE	10.8	11.4	7.2	10.1	11.4	10.0	9.9	7.6	11.5	9.7	11.3	10.8	9.5	11.8	12.6	9.6	8.5
SUM	148.7	152.9	157.5	151.7	155.6	142.9	143.9	147.1	144.3	154.8	144.9	140.4	163.8	151.2	147.3	151.4	162.4
Cpk	0.2	0.2	0.3	0.3	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Cpm	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Ppk	0.2	0.2	0.3	0.3	0.3	0.3	0.3	0.3	0.2	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.3
ALARM	- | -	- | -	- | -	- | -	- | -	- | -	- | -	- | -	- | -	- | -	- | -	- | -	- | -	- | -	- | -	- | -	- | -	- | -	- | -
NOTES	Y	Y	N	Y	N	N	N	N	N	N	N	Y	Y	N	N	N	N

[C#]
```
this.ChartTable.TableBackgroundMode =
    SPCGeneralizedTableDisplay.TABLE_SINGLE_COLOR_BACKGROUND_GRIDCELL;
this.ChartTable.BackgroundColor1 = Color.White;
this.ChartTable.BackgroundColor2 = Color.Gray;
```
[VB]
```
Me.ChartTable.TableBackgroundMode =
SPCGeneralizedTableDisplay.TABLE_SINGLE_COLOR_BACKGROUND_GRIDCELL
Me.ChartTable.BackgroundColor1 = Color.White
Me.ChartTable.BackgroundColor2 = Color.Gray
```

Table and Chart Fonts

There are a large number of fonts that you have control over, both the fonts in the table and the fonts in the chart. The programmer can select a default font (as in the case of non-US character set), or select individual fonts for different elements of the table and charts.

Table Fonts

The table fonts are accessed through the charts **ChartTable** property. Below is a list of accessible table fonts:

TimeLabelFont	The font used in the display of time values in the table.
SampleLabelFont	The font used in the display of sample numeric values in the table.
CalculatedLabelFont	The font used in the display of calculated values in the table.
StringLabelFont	The font used in the display of header string values in the table.
NotesLabelFont	The font used in the display of notes values in the table.

Extracted from the example
BatchAttributeControlCharts.PercentDefectivePartsControlChart

[C#]
```
this.ChartTable.SampleLabelFont = new Font("Times", 12, FontStyle.Regular);
```

[VB]
```
Me.ChartTable.SampleLabelFont = new Font("Times", 12, FontStyle.Regular)
```

The **ChartTable** class has a static property, **SPCGeneralizedTableDisplay.DefaultTableFont**, that sets the default Font. Use this if you want to establish a default font for all of the text in a table. This static property must be set BEFORE the charts **Init** routine.

Extracted from the example
BatchAttributeControlCharts.PercentDefectivePartsControlChart

[C#]
```
SPCGeneralizedTableDisplay.DefaultTableFont =
    new Font("Microsoft Sans Serif", 11, FontStyle.Regular);
// Initialize the SPCBatchVariableControlChart
this.InitSPCBatchAttributeControlChart(charttype, numcategories,
               numsamplespersubgroup, numdatapointsinview);
.
.
.
```

[VB]
```
SPCGeneralizedTableDisplay.DefaultTableFont = _
    new Font("Microsoft Sans Serif", 11, FontStyle.Regular)
' Initialize the SPCBatchAttrbiuteControlChart
Me.InitSPCBatchAttributeControlChart(charttype, numcategories, _
               numsamplespersubgroup, numdatapointsinview);
.
.
.
```

Chart Fonts
There are default chart fonts that are static objects in the **SPCChartObjects** class. They establish the default fonts for related chart objects and if you change them they need to be set before the first charts Init.. call. Since these properties are static, any changes to them will apply to the program as a whole, not just the immediate class.

AxisLabelFont	The font used to label the x- and y- axes.
AxisTitleFont	The font used for the axes titles.
HeaderFont	The font used for the chart title.
SubheadFont	The font used for the chart subhead.
ToolTipFont	The tool tip font.

AnnotationFont	The annotation font.
ControlLimitLabelFont	The font used to label the control limits

Extracted from the example TimeAttributeControlCharts.PercentDefectiveChart

[C#]
```
SPCChartObjects.AxisTitleFont = new Font("Times", 12, FontStyle.Regular);
SPCChartObjects.ControlLimitLabelFont = new Font("Times", 10, FontStyle.Regular);

this.InitSPCTimeAttributeControlChart(charttype, numcategories,
               numsamplespersubgroup, numdatapointsinview, timeincrementminutes);
```

[VB]
```
SPCChartObjects.AxisTitleFont = new Font("Times", 12, FontStyle.Regular)
SPCChartObjects.ControlLimitLabelFont = new Font("Times", 10, FontStyle.Regular)

Me.InitSPCTimeAttributeControlChart(charttype, numcategories, _
               numsamplespersubgroup, numdatapointsinview, timeincrementminutes)
```

The chart class static property, **DefaultTableFont**, sets the default Font string. Since the chart fonts all default to different sizes, the default font is defined using a string specifying the name of the font. This static property must be set BEFORE the charts **Init** routine.

Extracted from the example Extracted from the example TimeAttributeControlCharts.PercentDefectiveChart

[C#]
```
PercentDefectivePartsControlChart.DefaultChartFontString = "Times";
this.InitSPCTimeAttributeControlChart(charttype, numcategories,
               numsamplespersubgroup, numdatapointsinview, timeincrementminutes);
.
.
.
```

[VB]
```
PercentDefectivePartsControlChart.DefaultChartFontString = "Times"
Me.InitSPCTimeAttributeControlChart(charttype, numcategories, _
               numsamplespersubgroup, numdatapointsinview, timeincrementminutes)
.
.
```

These static properties establish the default fonts for a group of objects as a whole. For example, all charts will have the same x- and y-axis label fonts. You can still change the individual fonts for an individual object in a specific chart. For example, if in the Primary Chart you want the x-axis label font to be size 10, and the y-axis label font to be size 14, you can set them individually after the charts Init.. method has been called.

[C#]
```
this.InitSPCTimeAttributeControlChart(charttype, numcategories,
               numsamplespersubgroup, numdatapointsinview, timeincrementminutes);
.
.
this.PrimaryChart.XAxisLab.TextFont = new Font("Times", 10, FontStyle.Regular);
this.PrimaryChart.YAxisLab.TextFont = new Font("Times", 14, FontStyle.Regular);
```

[VB]

```
Me.InitSPCTimeAttributeControlChart(charttype, numcategories,
              numsamplespersubgroup, numdatapointsinview, timeincrementminutes)
.
.
Me.PrimaryChart.XAxisLab.TextFont = new Font("Times", 10, FontStyle.Regular)
Me.PrimaryChart.YAxisLab.TextFont = new Font("Times", 14, FontStyle.Regular)
```

Table and Chart Templates

All of the strings displayed in the table and charts use a template unique to the string type. Numeric strings use a **NumericLabel** template, time/date strings use a time **TimeLabel** template, and so on. These templates permit the programmer to customize the display of the strings. The various templates are listed below:

SPCChartObjects (Accessed in the charts PrimaryChart and SecondaryChart properties)

Property	Type	Description
XValueTemplate	NumericLabel	The x-value template for the data tooltip.
YValueTemplate	NumericLabel	The y-value template for the data tooltip.
XTimeValueTemplate	TimeLabel	x-value template for the data tooltip.
TextTemplate	ChartText	The text template for the data tooltip.

SPCGeneralizedTableDisplay (Accessed in the charts ChartTable property)

Property	Type	Description
TimeItemTemplate	TimeLabel	The TimeLabel object used as a template for displaying time values in the table.
SampleItemTemplate	NumericLabel	The NumericLabel object used as a template for displaying the sample values in the table.
CalculatedItemTemplate	NumericLabel	The NumericLabel object used as a template for displaying calculated values in the table.
StringItemTemplate	StringLabel	The StringLabel object used as a template for displaying string values in the table.
NotesItemTemplate	NotesLabel	The NotesLabel object used as a template for displaying string values in the table.

The most common use for these templates is to set the color attributes of a class of objects, or the decimal precision of a numeric string.

```
this.ChartTable.SampleItemTemplate.LineColor = Color.Red;
```

Chart Position

If the SPC chart does not include frequency histograms on the left (they take up about 20% of the available chart width), you can adjust the left and right edges of the chart using the **GraphStartPosX** and **GraphStopPlotX** properties to allow for more room in the display of the data. This also affects the table layout, because the table columns must line up with the chart data points.

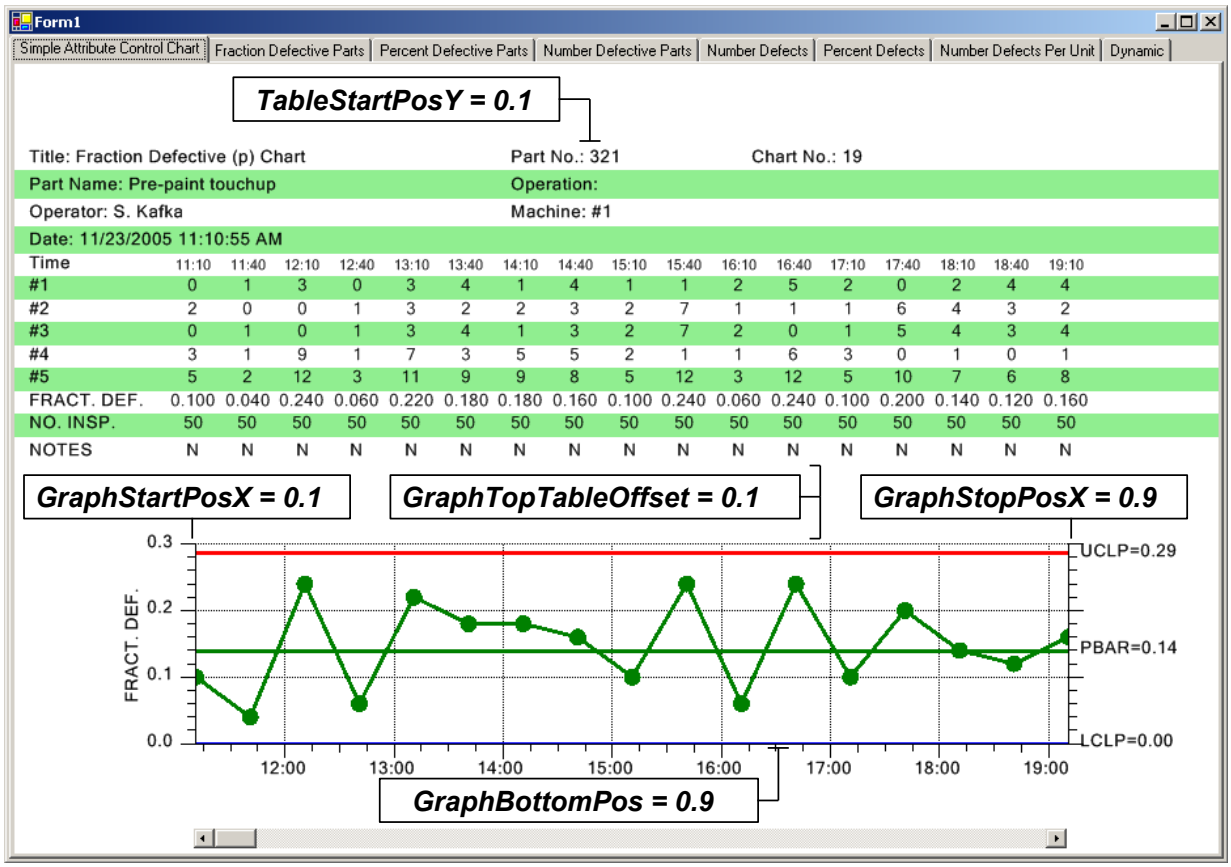
[C#]
```
this.GraphStartPosX = 0.1; // start here
this.GraphStopPosX = 0.875;  // end here
```

[VB]
```
Me.GraphStartPosX = 0.1 ' start here
Me.GraphStopPosX = 0.875  ' end here
```

There is not much flexibility positioning the top and bottom of the chart. Depending on the table items enabled, the table starts at the position defined by the **TableStartPosY** property, and continues until all of the table items are displayed. It then offsets the top of the primary chart with respect to the bottom of the table by the value of the property **GraphTopTableOffset**. The value of the property **GraphBottomPos** defines the bottom of the graph. The default values for these properties are:

```
TableStartPosY = 0.00
GraphTopTableOffset = 0.02
GraphBottomPos = 0.925
```

The picture below uses different values for these properties in order to emphasize the affect that these properties have on the resulting chart.


Form1
Simple Attribute Control Chart
Fraction Defective Parts
Percent Defective Parts
Number Defective Parts
Number Defects
Percent Defects
Number Defects Per Unit
Dynamic
TableStartPosY = 0.1
Title: Fraction Defective (p) Chart
Part No.: 321
Chart No.: 19
Part Name: Pre-paint touchup
Operation:
Operator: S. Kafka
Machine: #1
Date: 11/23/2005 11:10:55 AM
Time 11:10 11:40 12:10 12:40 13:10 13:40 14:10 14:40 15:10 15:40 16:10 16:40 17:10 17:40 18:10 18:40 19:10
#1 0 1 3 0 3 4 1 4 1 1 2 5 2 0 2 4 4
#2 2 0 0 1 3 2 2 3 2 7 1 1 1 6 4 3 2
#3 0 1 0 1 3 4 1 3 2 7 2 0 1 5 4 3 4
#4 3 1 9 1 7 3 5 5 2 1 1 6 3 0 1 0 1
#5 5 2 12 3 11 9 9 8 5 12 3 12 5 10 7 6 8
FRACT. DEF. 0.100 0.040 0.240 0.060 0.220 0.180 0.180 0.160 0.100 0.240 0.060 0.240 0.100 0.200 0.140 0.120 0.160
NO. INSP. 50 50 50 50 50 50 50 50 50 50 50 50 50 50 50 50 50
NOTES N N N N N N N N N N N N N N N N N
GraphStartPosX = 0.1
GraphTopTableOffset = 0.1
GraphStopPosX = 0.9
FRACT. DEF.
0.3
0.2
0.1
0.0
UCLP=0.29
PBAR=0.14
LCLP=0.00
12:00
13:00
14:00
15:00
16:00
17:00
18:00
19:00
GraphBottomPos = 0.9

SPC Control Limits

There are two methods you can use to set the SPC control limit for a chart. The first method explicitly sets the limits to values that you calculate on your own, because of some analysis that a quality engineer does on previously collected data. The second method auto-calculates the limits using the algorithms supplied in this software.

The quick way to set the limit values and limit strings is to use the charts **ChartData.SetControlLimitValues** and **ChartData.SetControlLimitStrings** methods. This method only works for the default +-3-sigma level control limits, and not any others you may have added using the charts **AddAdditionalControlLimit** method discussed in the *Multiple Control Limits* section. The data values in the *controllimitvalues* and *controllimitstrings* arrays used to pass the control limit information must be sorted in the following order:

[SPC_PRIMARY_CONTROL_TARGET,
SPC_PRIMARY_LOWER_CONTROL_LIMIT,
SPC_PRIMARY_UPPER_CONTROL_LIMIT]

[C#]

```
double [] controllimitvalues = {0.13, 0.0, 0.25};
this.ChartData.SetControlLimitValues(controllimitvalues);

string [] controllimitstrings = {"PBAR","LCL", "UCL”};
```

```
this.ChartData.SetControlLimitStrings(controllimitstrings);
```

[VB]

```
Dim controllimitvalues() As Double = {0.13, 0.0, 0.25}
Me.ChartData.SetControlLimitValues(controllimitvalues)

Dim controllimitstrings() As String = {"PBAR", "LCL", "UCL"}
Me.ChartData.SetControlLimitStrings(controllimitstrings)
```

You can also set the control limit values and control limit text one value at a time using the **ChartData.SetControlLimitValue** and **ChartData.SetControlLimitString** methods.

A more complicated way to set the control limits explicitly is to first grab a reference to the **SPCControlLimitRecord** for a given control limit, and then change the value of that control limit, and the control limit text, if desired. The example below sets the control limit values and text for the three control limits (target value, upper control limit, and lower control limit) of the primary chart, and the three control limit values for the secondary chart.

[C#]

```
// Set control limits for primary chart

//target control limit primary chart
SPCControlLimitRecord primarytarget =
    ChartData.GetControlLimitRecord(SPCControlChartData.SPC_PRIMARY_CONTROL_TARGET);
primarytarget.ControlLimitValue = 0.13;
primarytarget.ControlLimitText = "PBAR";

//lower control limit primary chart
SPCControlLimitRecord primarylowercontrollimit =
ChartData.GetControlLimitRecord(SPCControlChartData.SPC_PRIMARY_LOWER_CONTROL_LIMIT);
primarylowercontrollimit.ControlLimitValue = 0.0;
primarylowercontrollimit.ControlLimitText = "LCL";

//upper control limit primary chart
SPCControlLimitRecord primaryuppercontrollimit =
    ChartData.GetControlLimitRecord(SPCControlChartData.SPC_PRIMARY_UPPER_CONTROL_LIMIT);
primaryuppercontrollimit.ControlLimitValue = 0.25;
primaryuppercontrollimit.ControlLimitText = "UCL";
```

[VB]

```
' Set control limits for primary chart
'target control limit primary chart
Dim primarytarget As SPCControlLimitRecord = _
  ChartData.GetControlLimitRecord(SPCControlChartData.SPC_PRIMARY_CONTROL_TARGET)
primarytarget.ControlLimitValue = 0.13
primarytarget.ControlLimitText = "PBAR"

'lower control limit primary chart
Dim primarylowercontrollimit As SPCControlLimitRecord = _

ChartData.GetControlLimitRecord(SPCControlChartData.SPC_PRIMARY_LOWER_CONTROL_LIMI
T)
primarylowercontrollimit.ControlLimitValue = 0.0
primarylowercontrollimit.ControlLimitText = "LCL"

'upper control limit primary chart
Dim primaryuppercontrollimit As SPCControlLimitRecord = _

ChartData.GetControlLimitRecord(SPCControlChartData.SPC_PRIMARY_UPPER_CONTROL_LIMI
T)
primaryuppercontrollimit.ControlLimitValue = 0.25
```

```
primaryuppercontrollimit.ControlLimitText = "UCL"
```

The second way to set the control limits is to call the **AutoCalculateControlLimits** method. You must have already added a collection of sampled data values to the charts **ChartData** SPC data object before you can call this method, since the method uses the internal **ChartData** object to provide the historical values needed in the calculation.

[C#]
```
// Must have data loaded before any of the Auto.. methods are called
SimulateData();

// Calculate the SPC control limits for both graphs of the current SPC

this.AutoCalculateControlLimits();
```

[VB]
```
' Must have data loaded before any of the Auto.. methods are called
SimulateData()

' Calculate the SPC control limits for both graphs of the current SPC

Me.AutoCalculateControlLimits()
```

You can add data to the **ChartData** object, auto-calculate the control limits to establish the SPC control limits, and then continue to add new data values. Alternatively, you can set the SPC control limits explicitly as the result of previous runs, using the previously described **ChartData.SetControlLimitValues** method, and add new sampled data values to the **ChartData** object, and after a certain number of updates call the **AutoCalculateControlLimits** method to establish new control limits.

[C#]
```
updateCount++;
this.ChartData.AddNewSampleRecord(timestamp, samples);
if (updateCount > 50) // After 50 sample groups and calculate limits on the fly
{
// Calculate the SPC control limits for the X-Bar part of the current SPC chart
    this.AutoCalculateControlLimits();
    // Scale the y-axis of the X-Bar chart to display all data and control limits
    this.AutoScalePrimaryChartYRange();
}
```

[VB]
```
updateCount += 1
Me.ChartData.AddNewSampleRecord(timestamp, samples)
If updateCount > 50 Then ' After 50 sample groups and calculate limits on the fly
   ' Calculate the SPC control limits for the X-Bar part of the current SPC chart
   Me.AutoCalculateControlLimits()
   ' Scale the y-axis of the X-Bar chart to display all data and control limits
   Me.AutoScalePrimaryChartYRange()
End If
```

Need to exclude records from the control limit calculation? Call the **ChartData.ExcludeRecordFromControlLimitCalculations** method, passing in true to exclude the record.

[C#]
```
for (int i=0; i < 10; i++)
      this.ChartData.ExcludeRecordFromControlLimitCalculations(i,true);
```

[VB]
```
Dim i As Integer
For i = 0 To 9
   Me.ChartData.ExcludeRecordFromControlLimitCalculations(i, True)
Next i
```

Formulas Used in Calculating Control Limits for Attribute Control Charts

The SPC control limit formulas used in the software derive from the following source:

Fraction Defective Parts, Number Defective Parts, Number Defects, Number Defects Per Unit - "Introduction to Statistical Quality Control" by Douglas C. Montgomery, John Wiley and Sons, Inc. 2001.

Percent Defective Parts - "SPC Simplified – Practical Steps to Quality" by Robert T. Amsden, Productivity Inc., 1998.

SPC Control Chart Nomenclature

UCL = Upper Control Limit

LCL = Lower Control Limit

Center line = The target value for the process

p = estimate (or average) of the fraction defective (or non-conforming) parts

P = estimate (or average) of the percent defective (or non-conforming) parts

c = estimate (or average) of the number of defects (or nonconformities)

u = estimate (or average) of the number of defects (or nonconformities) per unit

n = number of samples per subgroup

dopu = defect opportunities per unit (applies only the DPMO chart)

dpmo = defects per million opportunities (applies only the DPMO chart)
calculated as: dpmo = (1,000,000 * numberOfDefects) / (sampleSize * dopu)

up = estimate (or average) of the dpmo values

Fraction Defective Parts – Also known as Fraction Non-Conforming or p-chart

UCL = p + 3 * Sqrt (p * (1- p) / n)

Center line = p

LCL = p - 3 * Sqrt (p * (1- p) / n)

Percent Defective Parts – Also known as Percent Non-Conforming or p-chart

UCL = p + 3 * Sqrt (p * (100% - p) / n)

Center line = p

LCL = p - 3 * Sqrt (p * (100% - p) / n)

Number of Defective Parts – Also known as the Number Nonconforming or np-chart

UCL = (n * p) + 3 * Sqrt ((n * p) * (1- p) / n)

Center line = (n * p)

LCL = (n * p) - 3 * Sqrt ((n * p) * (1- p) / n)

In this case the value (n * p) represents the average number of defective parts per sample subgroup. Since p is the estimate (or average) of the fraction defective per sample subgroup, n * p is the average number of defective per sample subgroup. Or you can add up all the number defective parts in all subgroups and divide by the number of subgroups, that to will reduce to the average number of defective per sample subgroup

Number Defects Per Million – Also known as DPMO

UCL = up + 3000 * Sqrt (up /(dopu * n))

Center line = up

LCL = up - 3000 * Sqrt (up/(dopu * n))

Number of Defects Control Chart – Also known as Number Nonconformities or c-chart

UCL = c + 3 * Sqrt (c)

Center line = c

LCL = c - 3 * Sqrt (c)

Number of Defects per Unit Control Chart – Also known as Number Nonconformities per Unit or u-chart

UCL = u + 3 * Sqrt (u / n)

Center line = u

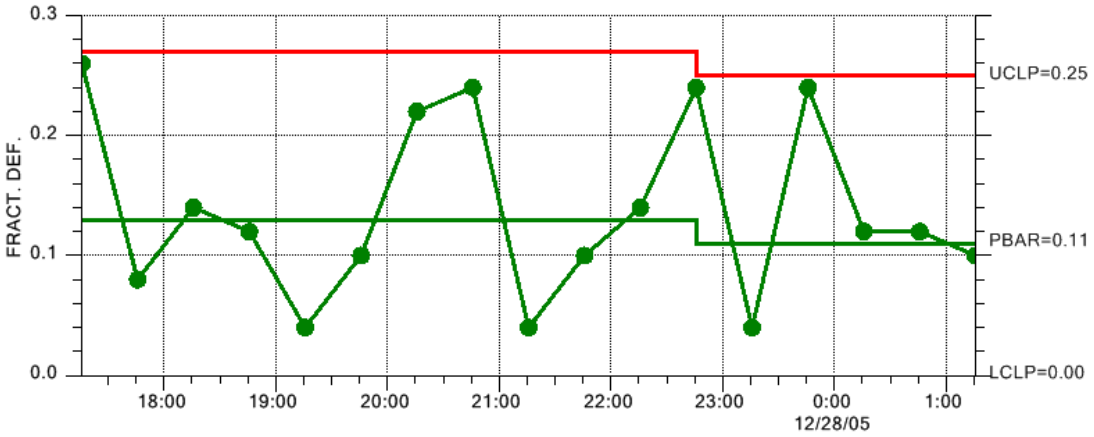
LCL = u - 3 * Sqrt (u / n)

Variable SPC Control Limits

There can be situations where the SPC control limit changes in a chart. If your control limits change, you need to set the following **ControlLineMode** property to SPCChartObjects.CONTROL_LINE_VARIABLE, as in the example below. The default value is SPCChartObjects.CONTROL_LINE_FIXED.

```
this.PrimaryChart.ControlLineMode = SPCChartObjects.CONTROL_LINE_VARIABLE;
```

In the SPCChartObjects.CONTROL_LINE_FIXED case, the current SPC control limit plots as a horizontal straight line for the entire width of the chart, regardless if the control limit changes, either explicitly, or using the **AutoCalculateControlLimits** method. If the **ControlLineMode** property is SPCChartObjects.CONTROL_LINE_VARIABLE, the SPC limit value plots at the value it had when the sample subgroup values updated. If you change a control limit value, the control limit line will no longer be a straight horizontal line, instead it will be jagged, or stepped, depending on the changes made.



There are three ways to enter new SPC limit values. See the example program TimeAttributeControlCharts.VariableControlLimits for an example of all three methods. First, you can use the method **ChartData.SetControlLimitValues** method.

[C#]

```
double [] initialControlLimits = {0.13, 0.0, 0.27};
double [] changeControlLimits = {0.11, 0.0, 0.25};
.
.
this.PrimaryChart.ControlLineMode = SPCChartObjects.CONTROL_LINE_VARIABLE;
.
.
// Change limits at sample subgroup 10
if (i== 10)
{
    this.ChartData.SetControlLimitValues(changeControlLimits);
}
this.ChartData.AddNewSampleRecord(timestamp, samples);
```

[VB]

```
Dim initialControlLimits As Double() = {0.13, 0.0, 0.27}
Dim changeControlLimits As Double() = {0.11, 0.0, 0.25}
.
.
Me.PrimaryChart.ControlLineMode = SPCChartObjects.CONTROL_LINE_VARIABLE
.
.
' Change limits at sample subgroup 10
If i = 10 Then
    Me.ChartData.SetControlLimitValues(changeControlLimits)
End If
```

```
Me.ChartData.AddNewSampleRecord(timestamp, samples)
```

Second, you can use the **AutoCalculateControlLimits** method. You must have already added a collection of sampled data values to the charts **ChartData** SPC data object before you can call this method, since the method uses the internal **ChartData** object to provide the historical values needed in the calculation.

[C#]

```
.
.
this.PrimaryChart.ControlLineMode = SPCChartObjects.CONTROL_LINE_VARIABLE;
.
.

// Variable Control Limits re-calculated every update after 10 using
//  AutoCalculateControlLimits
if (i > 10)
    this.AutoCalculateControlLimits();
this.ChartData.AddNewSampleRecord(timestamp, samples);
```

[VB]

```
.
.
Me.PrimaryChart.ControlLineMode = SPCChartObjects.CONTROL_LINE_VARIABLE
.
.

'  Variable Control Limits re-calculated every update after 10 using
'  AutoCalculateControlLimits
If i > 10 Then
  Me.AutoCalculateControlLimits()
End If
Me.ChartData.AddNewSampleRecord(timestamp, samples)
```

Last, you can enter the SPC control limits with every new sample subgroup record, using one of the methods that include a control limits array parameter.

[C#]

```
double [] initialControlLimits = {0.13, 0.0, 0.27};
double [] changeControlLimits = {0.11, 0.0, 0.25};
DoubleArray variableControlLimits;.
.
.
this.PrimaryChart.ControlLineMode = SPCChartObjects.CONTROL_LINE_VARIABLE;
.
.
//      Variable Control Limits updated using AddNewSampleRecord
    if (i== 10) // need to convert changeControlLimits to a DoubleArray
        variableControlLimits = new DoubleArray(changeControlLimits);
    this.ChartData.AddNewSampleRecord(timestamp, samples,
        variableControlLimits, notesstring);
```

[VB]

```
Dim initialControlLimits As Double() = {0.13, 0.0, 0.27}
```

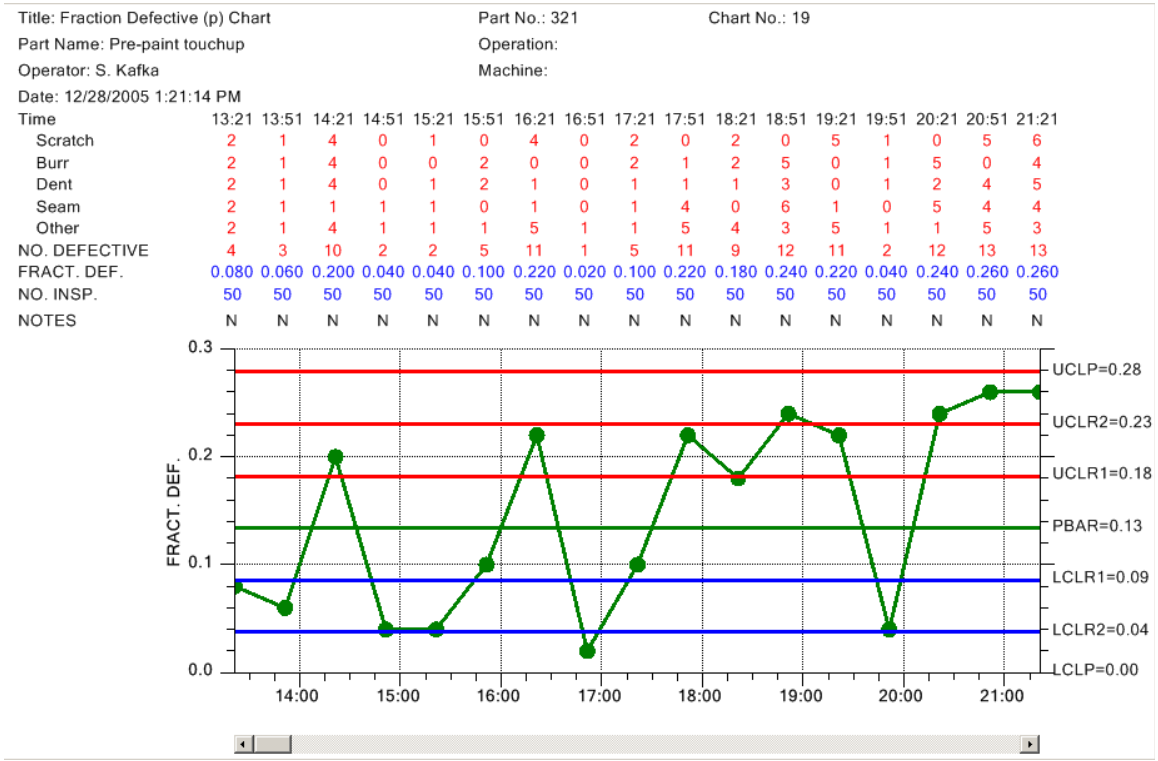
```
Dim changeControlLimits As Double() = {0.11, 0.0, 0.25}
Dim variableControlLimits As DoubleArray
.
.
this.PrimaryChart.ControlLineMode = SPCChartObjects.CONTROL_LINE_VARIABLE;
.
.
'   Variable Control Limits updated using AddNewSampleRecord
If i = 10 Then ' need to convert changeControlLimits to a DoubleArray
  variableControlLimits = New DoubleArray(changeControlLimits)
End If
Me.ChartData.AddNewSampleRecord(timestamp, samples, variableControlLimits)
```

Multiple SPC Control Limits

The normal SPC control limit displays at the 3-sigma level, both high and low.A common standard is that if the process variable under observation falls outside of the +-3-sigma limits the process is out of control. The default setup of our variable control charts have a high limit at the +3-sigma level, a low limit at the -3-sigma level, and a target value. There are situations where the quality engineer also wants to display control limits at the 1-sigma and 2-sigma level. The operator might receive some sort of preliminary warning if the process variable exceeds a 2-sigma limit.

.

You are able to add additional control limit lines to an attribute control chart, as in the example program TimeAttributeControlCharts.MultipleControlLimitsChart.



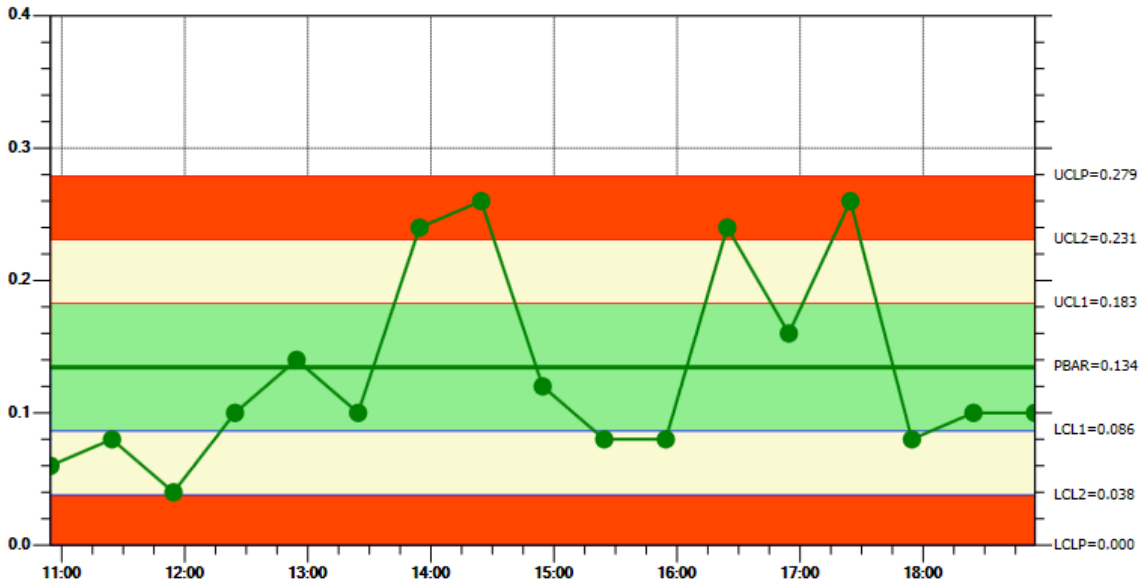
We added a method (**Add3SigmaControlLimits**) which will generate multiple control limits, for +-1, 2, and 3- sigma levels, based on an initial specification of the target value, and the +-3 sigma control limits. This is most useful if you want to generate +-1, 2 and 3-sigma control limits in order to fill in between them with a zone fill color. See the TimeAttributeControlCharts.MultiControlLimitsChart example. If you call the **AutoCalculateControlLimits** method, the initial +-1,2 and 3-sigma control limit values will be altered to the new, calculated values, but the control limit lines remain, with their new values. Since you do not normally want to be generating alarm messages for excursions into the +-1 and 2-sigma limit areas, the **Add3SigmaControl** limits has the option of disabling alarm notification in the case of +-1 and +-2 alarm conditions.

[C#]

```
double target = 0.14, lowlim = 0, highlim = 0.28;
bool limitcheck = false;
this.PrimaryChart.Add3SigmaControlLimits(target, lowlim, highlim, limitcheck);
this.PrimaryChart.ControlLimitLineFillMode = true;
```

[VB]

```
Dim target As Double = 0.14, lowlim As Double = 0, highlim As Double = 0.28
Dim limitcheck As Boolean = False
Me.PrimaryChart.Add3SigmaControlLimits(target, lowlim, highlim, limitcheck)
Me.PrimaryChart.ControlLimitLineFillMode = True
```



Control Limit Fill Option used with +-1, 2 and 3-sigma control limits

You can also add additional control limits one at a time. By default you get the +-3-sigma control limits. So additional control limits should be considered +-2-sigma and +-1-sigma control limits. Do not confuse control limits with specification limits, which must be

added using the **AddSpecLimit** method. There are two steps to adding additional control limits: creating a **SPCControlLimitRecord** object for the new control limit, and adding the control limit to the chart using the charts **AddAdditionalControlLimit** method**.** It is critical that you add them in a specific order, that order being:

Primary Chart	SPC_LOWER_CONTROL_LIMIT_2	(2-sigma lower limit)
Primary Chart	SPC_UPPER_CONTROL_LIMIT_2	(2-sigma upper limit)
Primary Chart	SPC_LOWER_CONTROL_LIMIT_1	(1-sigma lower limit)
Primary Chart	SPC_UPPER_CONTROL_LIMIT_1	(1-sigma upper limit)

[C#]

```
double sigma2 = 2.0;
double sigma1 = 1.0;
// Create multiple limits
// For PrimaryChart
SPCControlLimitRecord lcl2 = new SPCControlLimitRecord(this.ChartData,
SPCControlLimitRecord.SPC_LOWERTHAN_LIMIT, 0,"LCL2", "LCL2");
SPCControlLimitRecord ucl2 = new SPCControlLimitRecord(this.ChartData,
SPCControlLimitRecord.SPC_GREATERTHAN_LIMIT, 0.28,"UCL2", "UCL2");

this.PrimaryChart.AddAdditionalControlLimit(lcl2,
SPCChartObjects.SPC_LOWER_CONTROL_LIMIT_2, sigma2);
this.PrimaryChart.AddAdditionalControlLimit(ucl2,
SPCChartObjects.SPC_UPPER_CONTROL_LIMIT_2, sigma2);

SPCControlLimitRecord lcl3 = new SPCControlLimitRecord(this.ChartData,
SPCControlLimitRecord.SPC_LOWERTHAN_LIMIT, 0.07,"LCL1", "LCL1");
SPCControlLimitRecord ucl3 = new SPCControlLimitRecord(this.ChartData,
SPCControlLimitRecord.SPC_GREATERTHAN_LIMIT, 0.21,"UCL1", "UCL1");

this.PrimaryChart.AddAdditionalControlLimit(lcl3,
SPCChartObjects.SPC_LOWER_CONTROL_LIMIT_1, sigma1);
this.PrimaryChart.AddAdditionalControlLimit(ucl3,
SPCChartObjects.SPC_UPPER_CONTROL_LIMIT_1, sigma1);
```

[VB]

```
Dim sigma2 As Double = 2.0
Dim sigma1 As Double = 1.0
' Create multiple limits
' For PrimaryChart
Dim lcl2 As SPCControlLimitRecord = New SPCControlLimitRecord(Me.ChartData,
SPCControlLimitRecord.SPC_LOWERTHAN_LIMIT, 0, "LCL2", "LCL2")
Dim ucl2 As SPCControlLimitRecord = New SPCControlLimitRecord(Me.ChartData,
SPCControlLimitRecord.SPC_GREATERTHAN_LIMIT, 0.28, "UCL2", "UCL2")

Me.PrimaryChart.AddAdditionalControlLimit(lcl2,
SPCChartObjects.SPC_LOWER_CONTROL_LIMIT_2, sigma2)
Me.PrimaryChart.AddAdditionalControlLimit(ucl2,
SPCChartObjects.SPC_UPPER_CONTROL_LIMIT_2, sigma2)

Dim lcl3 As SPCControlLimitRecord = New SPCControlLimitRecord(Me.ChartData,
SPCControlLimitRecord.SPC_LOWERTHAN_LIMIT, 0.07, "LCL1", "LCL1")
Dim ucl3 As SPCControlLimitRecord = New SPCControlLimitRecord(Me.ChartData,
SPCControlLimitRecord.SPC_GREATERTHAN_LIMIT, 0.21, "UCL1", "UCL1")

Me.PrimaryChart.AddAdditionalControlLimit(lcl3,
SPCChartObjects.SPC_LOWER_CONTROL_LIMIT_1, sigma1)
Me.PrimaryChart.AddAdditionalControlLimit(ucl3,
SPCChartObjects.SPC_UPPER_CONTROL_LIMIT_1, sigma1)
```

Special Note – When you create a **SPCControlLimitRecord** object, you can specify an actual limit level. If you do not call the charts **AutoCalculateControlLimits** method, the

control limit will be displayed at that value. If you do call **AutoCalculateControlLimits** method, the auto-calculated value overrides the initial value (0.0 in the examples above). When you call the charts **AddAdditionalControlLimits** method, you specify the sigma level that is used by the **AutoCalculateControlLimits** to calculate the control limit level.

If you want the control limits displayed as filled areas, set the charts **ControlLimitLineFillMode** property True.

```
[C#]
spcChart.PrimaryChart.ControlLimitLineFillMode = true;
```

This will fill each control limit line from the limit line to the target value of the chart. In order for the fill to work properly, you must set this property after you define all additional control limits. Also, you must add the outer most control limits (SPC_UPPER_CONTROL_LIMIT_3 and SPC_LOWER_CONTROL_LIMIT_3) first, followed by the next outer most limits (SPC_UPPER_CONTROL_LIMIT_2 and SPC_LOWER_CONTROL_LIMIT_2), followed by the inner most control limits (SPC_UPPER_CONTROL_LIMIT_1 and SPC_LOWER_CONTROL_LIMIT_1). This way the fill of the inner limits will partially cover the fill of the outer limits, creating the familiar striped look you want to see.

Chart Y-Scale

You can set the minimum and maximum values of the two charts y-scales manually using the **PrimaryChart.MinY**, **PrimaryChart.MaxY**, **SecondaryChartMinY** and **SecondaryChartMaxY** properties.

[C#]

```
// Set initial scale of the y-axis of the mean chart
// If you are calling AutoScalePrimaryChartYRange this isn't really needed
this.PrimaryChart.MinY = 0;
this.PrimaryChart.MaxY = 40;
```

[VB]

```
' Set initial scale of the y-axis of the mean chart
' If you are calling AutoScalePrimaryChartYRange this isn't really needed
Me.PrimaryChart.MinY = 0
Me.PrimaryChart.MaxY = 40
```

It is easiest to just call the auto-scale routines after the chart has been initialized with data, and any control limits calculated.

[C#]

```
// Must have data loaded before any of the Auto.. methods are called
    SimulateData();

// Calculate the SPC control limits for both graphs of the current SPC chart
```

```
    this.AutoCalculateControlLimits();

// Scale the y-axis of the X-Bar chart to display all data and control limits
    this.AutoScalePrimaryChartYRange();
```

[VB]

```
' Must have data loaded before any of the Auto.. methods are called
SimulateData()

' Calculate the SPC control limits for both graphs of the current SPC chart
Me.AutoCalculateControlLimits()

' Scale the y-axis of the X-Bar chart to display all data and control limits
Me.AutoScalePrimaryChartYRange()
```

Once all of the graph parameters are set, call the method **RebuildChartUsingCurrentData**.

[C#]

```
// Rebuild the chart using the current data and settings
this.RebuildChartUsingCurrentData();
```

[VB]

```
' Rebuild the chart using the current data and settings
Me.RebuildChartUsingCurrentData()
```

If, at any future time you change any of the chart properties, you will need to call **RebuildChartUsingCurrentData** to force a rebuild of the chart, taking into account the current properties. **RebuildChartUsingCurrentData** invalidates the chart and forces a redraw**.** Our examples that update dynamically demonstrate this technique. The chart is setup with some initial settings and data values. As data is added in real-time to the graph, the chart SPC limits, and y-scales are constantly recalculated to take into account new data values. The code below is extracted from the **TimeAttributeControlCharts.DynamicAttributeControlChart** example program.

[C#]

```
private void timer1_Tick(object sender, System.EventArgs e)
{
    ChartCalendar timestamp = (ChartCalendar) startTime.Clone();
    // This simulates an assignable defect for each category, the last category
    //  is assigned the total number of defective parts, not defects.
    DoubleArray samples = this.ChartData.SimulateDefectRecord(50 * 0.134,
        SPCControlChartData.PERCENT_DEFECTIVE_PARTS_CHART);
    // Add new sample record
    this.ChartData.AddNewSampleRecord(timestamp, samples);
    // Simulate 30  minute passing
    startTime.Add(ChartObj.MINUTE, 30);

    // Calculate the SPC control limits
    this.AutoCalculatePrimaryControlLimits();
    // Scale the y-axis of the SPC chart to display all data and control limits
    this.AutoScalePrimaryChartYRange();
    // Rebuild the chart using the current data and settings
    this.RebuildChartUsingCurrentData();
}
```

[VB]

```
Private Sub Timer1_Tick(ByVal sender As System.Object,
    ByVal e As System.EventArgs) Handles Timer1.Tick
    Dim timestamp As ChartCalendar = CType(startTime.Clone(), ChartCalendar)
    ' This simulates an assignable defect for each category, the last category
    '  is assigned the total number of defective parts, not defects.
    Dim samples As DoubleArray = _
        Me.ChartData.SimulateDefectRecord(50 * 0.134, _
        SPCControlChartData.PERCENT_DEFECTIVE_PARTS_CHART)
    ' Add new sample record
     Me.ChartData.AddNewSampleRecord(timestamp, samples)
    ' Simulate 30  minute passing
    startTime.Add(ChartObj.MINUTE, 30)

    ' Calculate the SPC control limits
    Me.AutoCalculatePrimaryControlLimits()
    ' Scale the y-axis of the SPC chart to display all data and control limits
    Me.AutoScalePrimaryChartYRange()
    ' Rebuild the chart using the current data and settings
    Me.RebuildChartUsingCurrentData()
    Me.UpdateDraw()
End Sub 'timer1_Tick
```

Updating Chart Data

The real-time example above demonstrates how the SPC chart data is updated, using the **ChartData.AddNewSampleRecord** method. In this case, the chart data updates with each timer tick event, though it could just as easily be any other type of event. If you have already collected all of your data and just want to plot it all at once, use a simple loop like most of our examples do to update the data.

[C#]

```
private void SimulateData()
{
    if (this.IsDesignMode) return;

    for (int i=0; i < 200; i++)
    {
        ChartCalendar timestamp = (ChartCalendar) startTime.Clone();
    // This simulates an assignable defect for each category, the last category
    //  is assigned the total number of defective parts, not defects.
        DoubleArray samples = this.ChartData.SimulateDefectRecord(50 * 0.134,
            SPCControlChartData.PERCENT_DEFECTIVE_PARTS_CHART);
    // Add new sample record
        this.ChartData.AddNewSampleRecord(timestamp, samples);
        // Simulate 30  minute passing
        startTime.Add(ChartObj.MINUTE, 30);
    }
}
```

[VB]

```
Private Sub SimulateData()
   If Me.IsDesignMode Then
      Return
   End If
   Dim i As Integer
   For i = 0 To 199
      Dim timestamp As ChartCalendar = CType(startTime.Clone(), ChartCalendar)
```

```
      ' This simulates an assignable defect for each category, the last category
      '  is assigned the total number of defective parts, not defects.
      Dim samples As DoubleArray = _
           Me.ChartData.SimulateDefectRecord(50 * 0.134, _
            SPCControlChartData.PERCENT_DEFECTIVE_PARTS_CHART)
      ' Add new sample record
      Me.ChartData.AddNewSampleRecord(timestamp, samples)
      ' Simulate 30  minute passing
      startTime.Add(ChartObj.MINUTE, 30)
   Next i
End Sub 'SimulateData
```

In this example the sample data and the time stamp for each sample record is simulated. In your application, you will probably be reading the sample record values from some sort of database or file, along with the actual time stamp for that data.

If you want to append a text note to a sample record, use one of the **ChartData.AddNewSampleRecord** overrides that have a *notes* parameter. The code below is extracted from **the TimeAttributeControlCharts.SimpleAttributeControlChart** example.

[C#]

```
private void SimulateData()
{   String notesstring = "";
    if (this.IsDesignMode) return;
    for (int i=0; i < 200; i++)
    {
        ChartCalendar timestamp = (ChartCalendar) startTime.Clone();
    // This simulates an assignable defect for each category, the last category
    //  is assigned the total number of defective parts, not defects.
        DoubleArray samples = this.ChartData.SimulateDefectRecord(50 * 0.134,
            SPCControlChartData.PERCENT_DEFECTIVE_PARTS_CHART);
        double r = ChartSupport.GetRandomDouble();
        if (r < 0.1) // make a note on every tenth item, on average
            notesstring = "Note for sample subgroup #" + i.ToString() +
                ". Spray paint nozzel clogged. Replaced with new, Enois nozzle.";
        else
            notesstring = "";
        // Add new sample record
        this.ChartData.AddNewSampleRecord(timestamp, samples, notesstring);
        // Simulate 30  minute passing
        startTime.Add(ChartObj.MINUTE, 30);
    }
}
```

[VB]

```
Private Sub SimulateData() '
   Dim notesstring As [String] = ""
   If Me.IsDesignMode Then
     Return
   End If
   Dim i As Integer
   For i = 0 To 199
    Dim timestamp As ChartCalendar = CType(startTime.Clone(), ChartCalendar)
    ' This simulates an assignable defect for each category, the last category
    '  is assigned the total number of defective parts, not defects.
    Dim samples As DoubleArray = Me.ChartData.SimulateDefectRecord(50 * 0.134, _
         SPCControlChartData.PERCENT_DEFECTIVE_PARTS_CHART)

     Dim r As Double = ChartSupport.GetRandomDouble()
     If r < 0.1 Then ' make a note on every tenth item, on average
         notesstring = "Note for sample subgroup #" + i.ToString() + _
```

```
            ". Spray paint nozzel clogged. Replaced with new, Enois nozzle."
      Else
          notesstring = ""
      End If
      ' Add new sample record
       Me.ChartData.AddNewSampleRecord(timestamp, samples, notesstring)
      ' Simulate 30  minute passing
       startTime.Add(ChartObj.MINUTE, 30)
   Next i
End Sub 'SimulateData
```

Scatter Plots of the Actual Sampled Data

This option is not applicable for attribute control charts.

Enable Chart ScrollBar

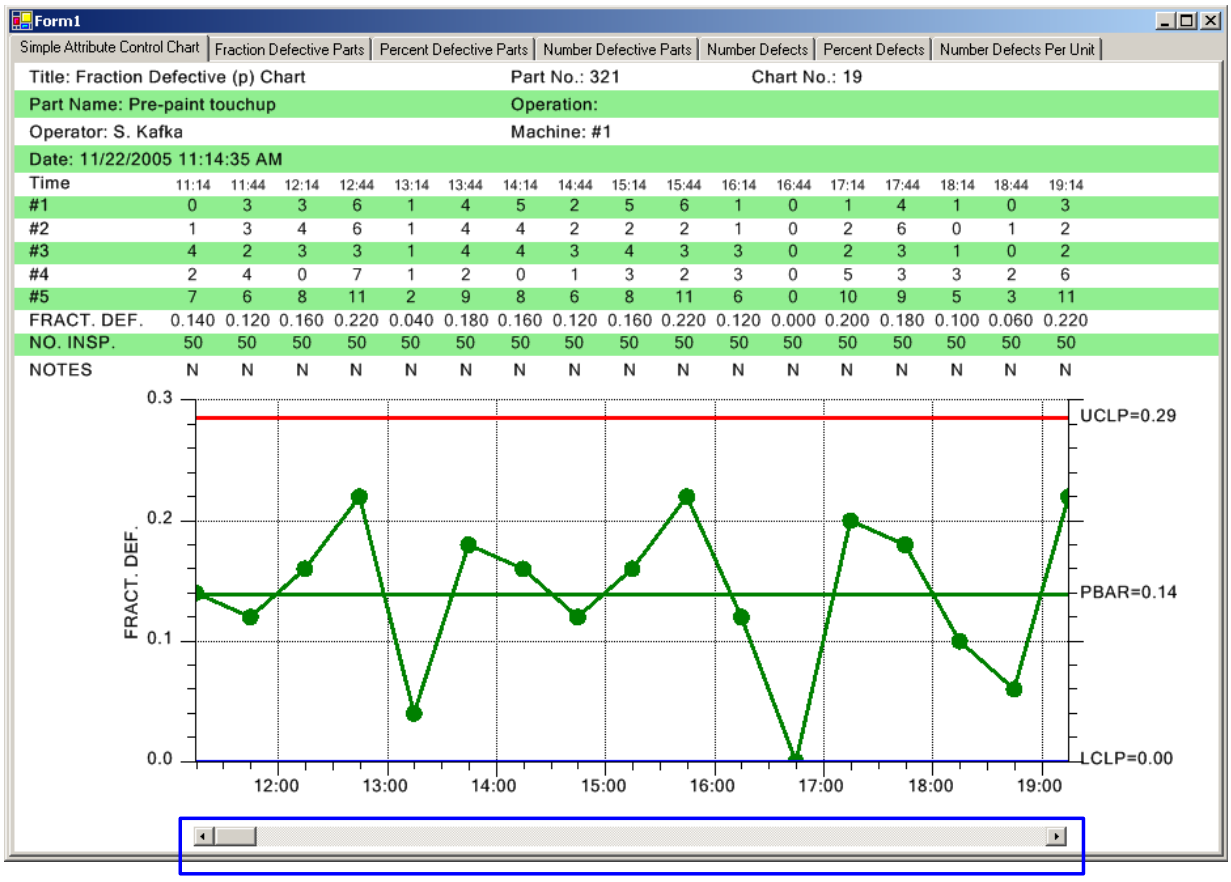
Set the **EnableScrollBar** property true to enable the chart scrollbar. You will then be able to window in on 8-20 sample subgroups at a time, from a much larger collection of measurement data representing hundreds or even thousands of subgroups, and use the scrollbar to move through the data, similar to paging through a spreadsheet.

[C#]

```
// enable scroll bar
this.EnableScrollBar = true;
```

[VB]

```
' Enable scroll bar
Me.EnableScrollBar = True
```



Scrollbar

SPC Chart Histograms

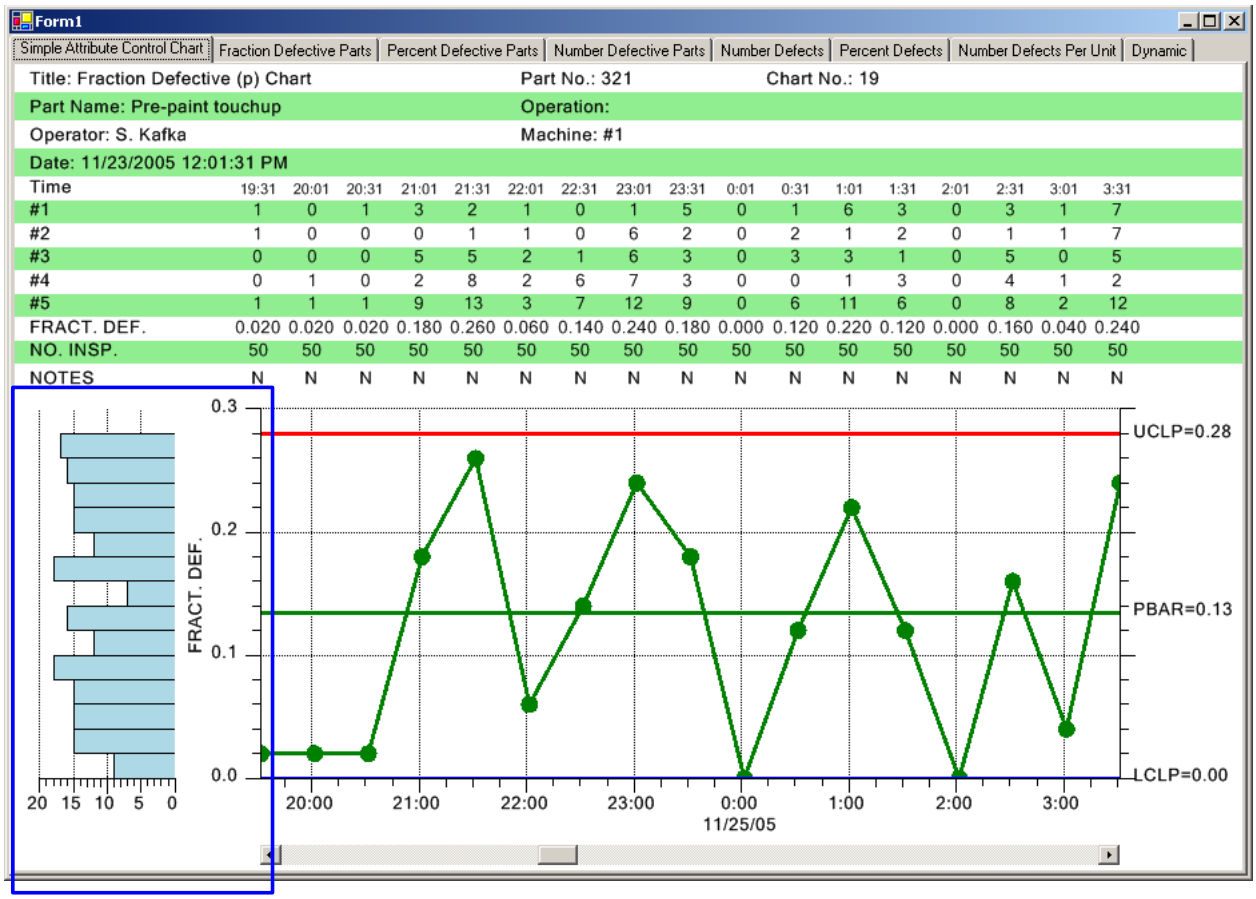
Viewing frequency histograms of the variation in the primary variable side-by-side with the SPC control chart makes it even easier to find out whether the variations are the result of natural variations or the result of some systemic change in the process. You can turn on integrated frequency histograms for either chart using the **PrimaryChart.DisplayFrequencyHistogram** property of the chart.

[C#]

```
//  frequency histogram for both charts
this.PrimaryChart.DisplayFrequencyHistogram = true;
```

[VB]

```
'  frequency histogram for both charts
Me.PrimaryChart.DisplayFrequencyHistogram = True
```

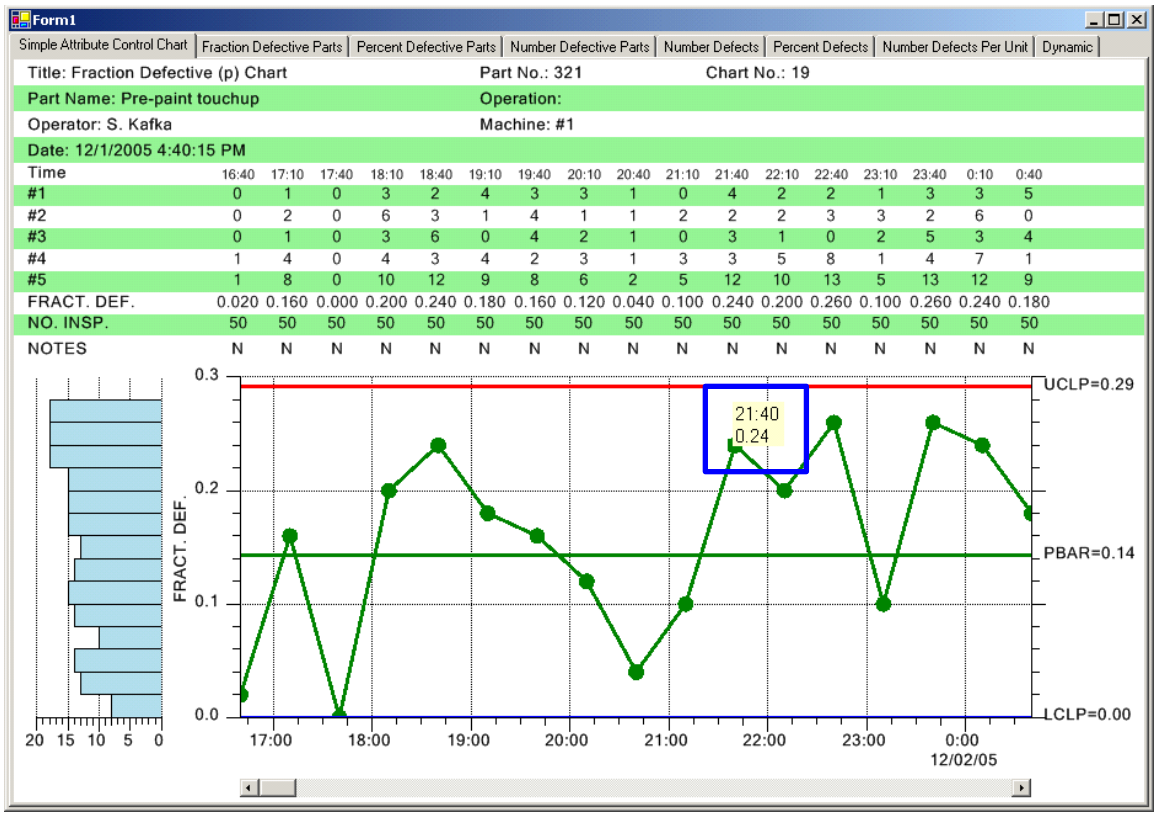


Frequency Histogram

SPC Chart Data and Notes Tooltips

You can invoke two types of tooltips using the mouse. The first is a data tooltip. When you hold the mouse button down over one of the data points in the primary chart, the x and y values for that data point display in a popup tooltip..

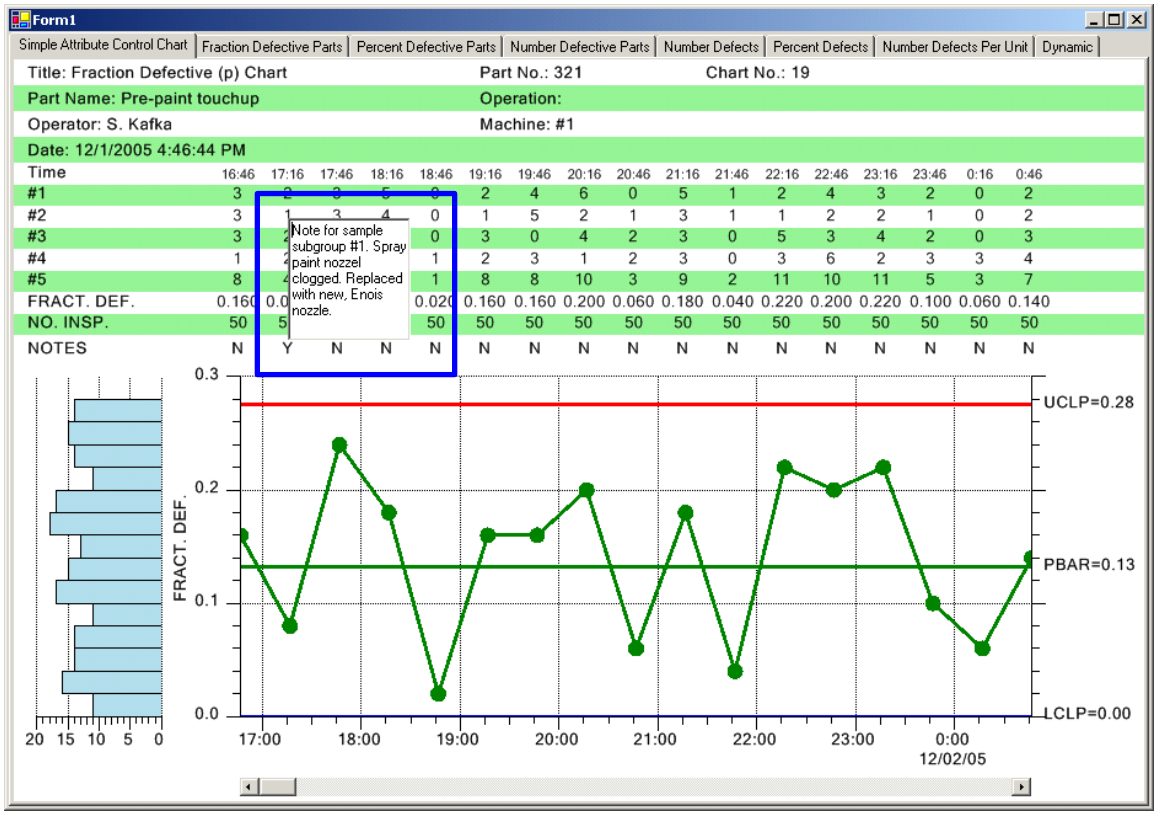
Data Tooltip



If you are displaying the Notes line in the table portion of the chart, the Notes entry for a sample subgroup displays “Y” if a note was recorded for that sample subgroup, or “N” if

no note was recorded. Notes are recorded using one of the **ChartData.AddNewSampleRecord** overrides that include a notes parameter. See the section Updating Chart Data. If you click on a "Y" in the Notes row for a sample subgroup, the complete text of the note for that sample subgroup will display in a RichTextBox, immediately above the "Y". You can actually edit the notes in the RichTextBox.

Notes Tooltip



[C#]

```
private void SimulateData()
{   String notesstring = "";
    if (this.IsDesignMode) return;
    for (int i=0; i < 200; i++)
    {
        .
        .
        .
        // Add new sample record
        this.ChartData.AddNewSampleRecord(timestamp, samples, notesstring);
        // Simulate 30  minute passing
        startTime.Add(ChartObj.MINUTE, 30);
    }
}
```

[VB]

```
Private Sub SimulateData()
   Dim notesstring As [String] = ""
   If Me.IsDesignMode Then
      Return
```

```
   End If
   Dim i As Integer
   For i = 0 To 199
        .
        .
        .

      ' Add new sample record
      Me.ChartData.AddNewSampleRecord(timestamp, samples, notesstring)
      ' Simulate 30  minute passing
      startTime.Add(ChartObj.MINUTE, 30)
   Next i
End Sub 'SimulateData
```

Both kinds of tooltips are on by default. Turn the tooltips on or off in the program using the **EnableDataToolTip** and **EnableNotesToolTip** flags.

[C#]
```
// Enable data and notes tooltips
this.EnableDataToolTip = true;
this.EnableNotesToolTip = true;
```

[VB]
```
' Enable data and notes tooltips
Me.EnableDataToolTip = True
Me.EnableNotesToolTip = True
```

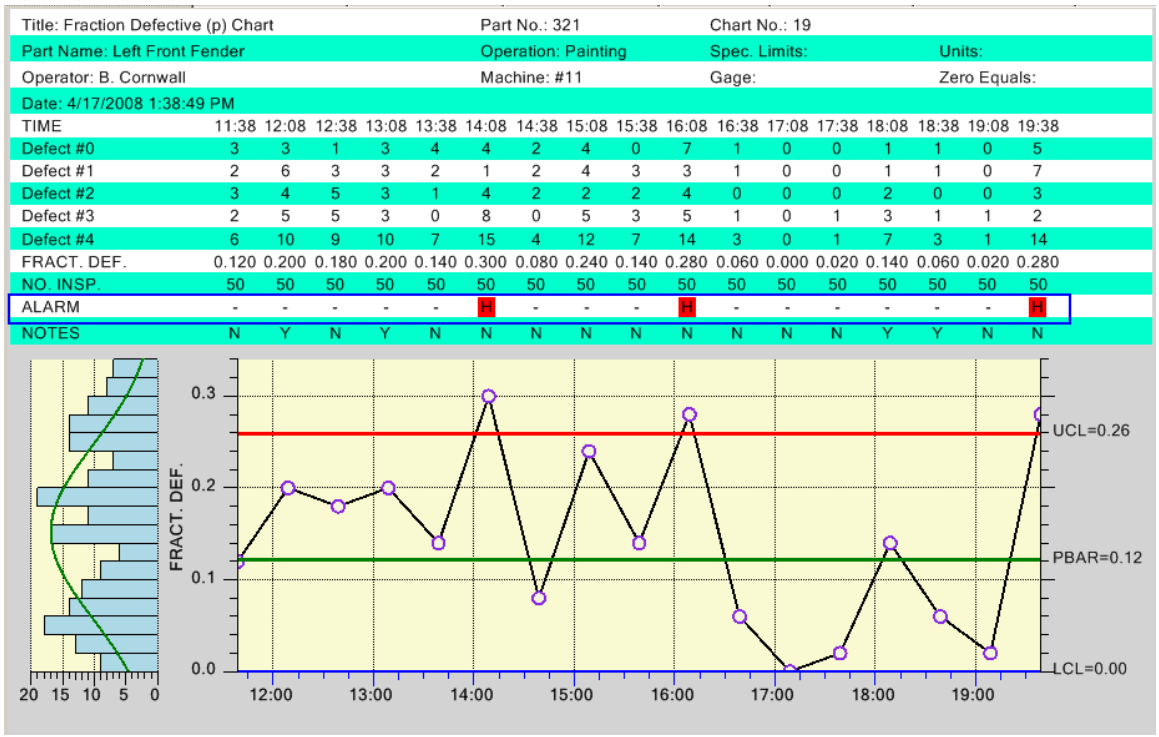
The notes tooltip has an additional option. In order to make the notes tooltip “editable”, the tooltip, which is .Net RichEditBox, displays on the first click, and goes away on the second click. You can click inside the RichTextBox and not worry the tooltip suddenly disappearing. The notes tooltip works this way by default. If you wish to explicitly set it, or change it so that the tooltip only displays while the mouse button is held down, as the data tooltips do, set the **ChartData.NotesToolTips.ToolTipMode** property to **NotesToolTip.MOUSEDOWN_TOOLTIP**, as in the example below.

[C#]
```
// Enable data and notes tooltips
this.EnableDataToolTip = true;
this.EnableNotesToolTip = true;

this.ChartData.NotesToolTips.ButtonMask = MouseButtons.Right;
// default is MOUSETOGGLE_TOOLTIP
this.ChartData.NotesToolTips.ToolTipMode= NotesToolTip.MOUSEDOWN_TOOLTIP;
```

[VB]
```
' Enable data and notes tooltips
Me.EnableDataToolTip = True
Me.EnableNotesToolTip = True

Me.ChartData.NotesToolTips.ButtonMask = MouseButtons.Right
' default is MOUSETOGGLE_TOOLTIP
Me.ChartData.NotesToolTips.ToolTipMode = NotesToolTip.MOUSEDOWN_TOOLTIP
```

Enable Alarm Highlighting

EnableAlarmStatusValues



Title: Fraction Defective (p) Chart						Part No.: 321				Chart No.: 19							
Part Name: Left Front Fender						Operation: Painting				Spec. Limits:				Units:			
Operator: B. Cornwall						Machine: #11				Gage:				Zero Equals:			
Date: 4/17/2008 1:38:49 PM																	
TIME	11:38	12:08	12:38	13:08	13:38	14:08	14:38	15:08	15:38	16:08	16:38	17:08	17:38	18:08	18:38	19:08	19:38
Defect #0	3	3	1	3	4	4	2	4	0	7	1	0	0	1	1	0	5
Defect #1	2	6	3	3	2	1	2	4	3	3	1	0	0	1	1	0	7
Defect #2	3	4	5	3	1	4	2	2	2	4	0	0	0	2	0	0	3
Defect #3	2	5	5	3	0	8	0	5	3	5	1	0	1	3	1	1	2
Defect #4	6	10	9	10	7	15	4	12	7	14	3	0	1	7	3	1	14
FRACT. DEF.	0.120	0.200	0.180	0.200	0.140	0.300	0.080	0.240	0.140	0.280	0.060	0.000	0.020	0.140	0.060	0.020	0.280
NO. INSP.	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50
ALARM	-	-	-	-	-	H	-	-	-	H	-	-	-	-	-	-	H
NOTES	N	Y	N	Y	N	N	N	N	N	N	N	N	N	Y	Y	N	N

There are several alarm highlighting options you can turn on and off. The alarm status line above is turned on/off using the EnableAlarmStatusValues property. We have set it on by default, so you will have to turn it off if you don't want it. Each sample interval has two small boxes that are labeled using one of several different characters, listed below. The most common are an "H" signifying a high alarm, a "L" signifying a low alarm, and a "-" signifying that there is no alarm. When specialized control rules are implemented, either using the named rules discussed in Chapter 8, or custom rules involving trending, oscillation, or stratification, a "T", "O" or "S" may also appear.

"-"	No alarm condition
"H"	High - Measured value is above a high limit
"L"	Low - Measured value falls below a low limit
"T"	Trending - Measured value is trending up (or down).
"O"	Oscillation - Measured value is oscillating (alternating) up and down.
"S"	Stratification - Measured value is stuck in a narrow band.

[C#]

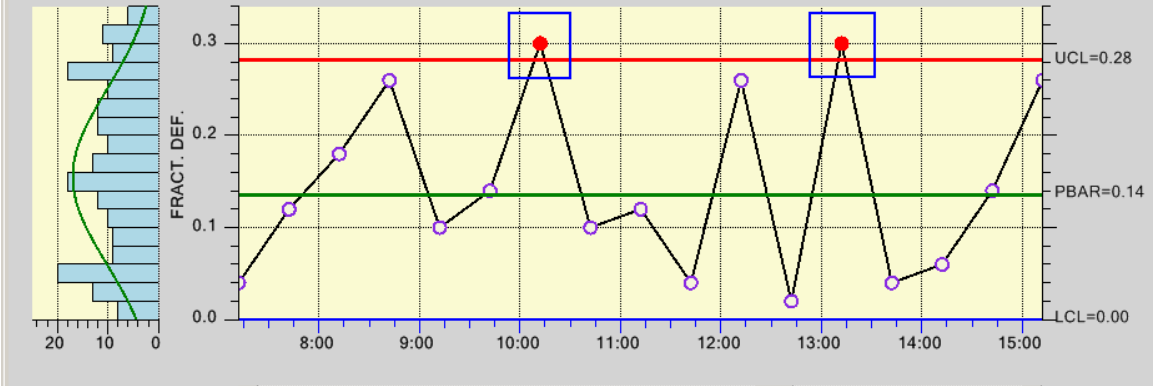
```
// Alarm status line
this.EnableAlarmStatusValues = false;
```

[VB]

```
'Alarm status line
Me.EnableAlarmStatusValues = False
```

ChartAlarmEmphasisMode

Title: Fraction Defective (p) Chart						Part No.: 321					Chart No.: 19						
Part Name: Left Front Fender						Operation: Painting					Spec. Limits:				Units:		
Operator: B. Cornwall						Machine: #11					Gage:				Zero Equals:		
Date: 4/17/2008 1:42:06 PM																	
TIME	7:12	7:42	8:12	8:42	9:12	9:42	10:12	10:42	11:12	11:42	12:12	12:42	13:12	13:42	14:12	14:42	15:12
Defect #0	0	2	0	7	1	0	6	1	3	1	1	0	1	1	1	4	7
Defect #1	0	2	6	4	0	0	5	1	4	1	3	1	8	1	0	1	7
Defect #2	1	3	5	5	1	2	6	2	4	1	4	0	3	0	1	4	7
Defect #3	1	1	4	0	3	5	9	2	3	1	5	1	3	1	1	4	5
Defect #4	2	6	9	13	5	7	15	5	6	2	13	1	15	2	3	7	13
FRACT. DEF.	0.040	0.120	0.180	0.260	0.100	0.140	0.300	0.100	0.120	0.040	0.260	0.020	0.300	0.040	0.060	0.140	0.260
NO. INSP.	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50
ALARM	-	-	-	-	-	-	H	-	-	-	-	-	H	-	-	-	-
NOTES	N	N	N	N	N	N	N	Y	N	N	N	Y	N	N	N	N	N



[C#]

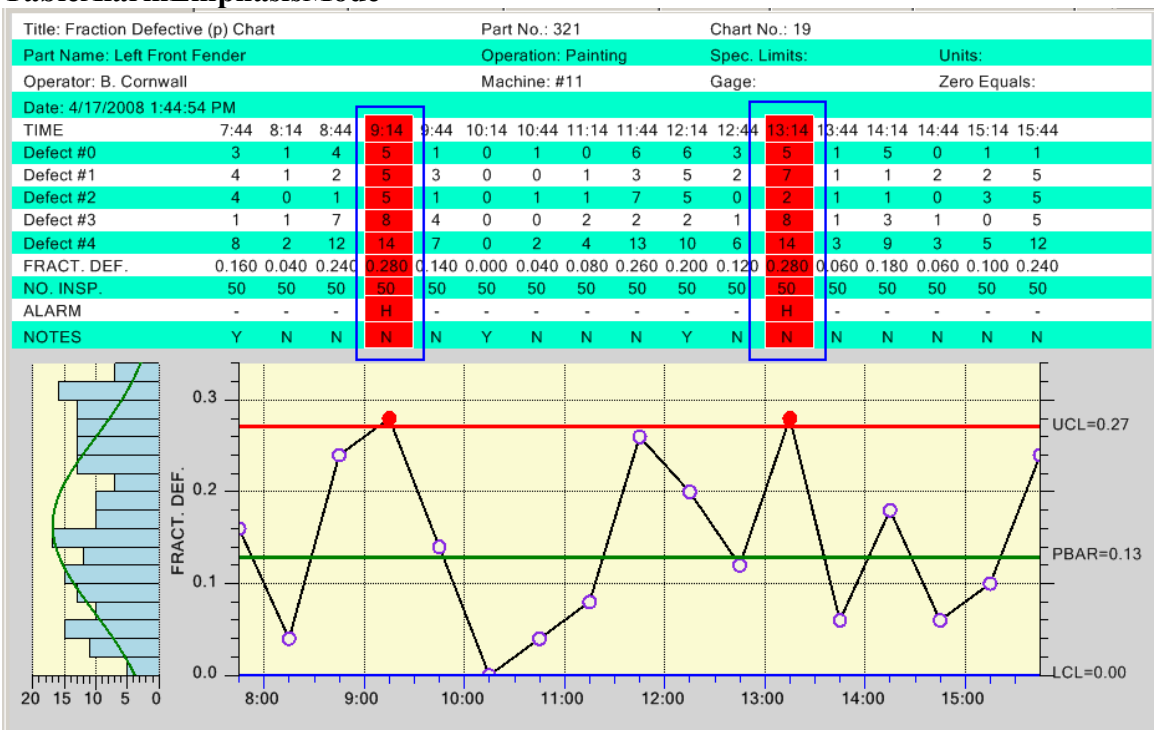
```
// Chart alarm emphasis mode
this.ChartAlarmEmphasisMode = SPCChartBase.ALARM_HIGHLIGHT_SYMBOL;
```

[VB]

```
' Chart alarm emphasis mode
Me.ChartAlarmEmphasisMode = SPCChartBase.ALARM_HIGHLIGHT_SYMBOL
```

The scatter plot symbol used to plot a data point in the chart is normally a fixed color circle. If you turn on the alarm highlighting for chart symbols the symbol color for a sample interval that is in an alarm condition will change to reflect the color of the associated alarm line. In the example above, a low alarm (blue circle) occurs at the beginning of the chart and a high alarm (red circle) occurs at the end of the chart. Alarm symbol highlighting is turned on by default. To turn it off use the SPCChartBase.ALARM_NO_HIGHLIGHT_SYMBOL constants.

TableAlarmEmphasisMode -



C#]

```
// Table alarm emphasis mode
this.TableAlarmEmphasisMode = SPCChartBase.ALARM_HIGHLIGHT_BAR;
```

[VB]

```
' Table alarm emphasis mode
Me.TableAlarmEmphasisMode = SPCChartBase.ALARM_HIGHLIGHT_BAR
```

The entire column of the data table can be highlighted when an alarm occurs. There are four modes associated with this property:

ALARM_HIGHLIGHT_NONE	No alarm highlight
ALARM_HIGHLIGHT_TEXT	Text alarm highlight
ALARM_HIGHLIGHT_OUTLINE	Outline alarm highlight
ALARM_HIGHLIGHT_BAR	Bar alarm highlight

The example above uses the ALARM_HIGHLIGHT_BAR mode.

Title: Fraction Defective (p) Chart					Part No.: 321				Chart No.: 19							
Part Name: Left Front Fender					Operation: Painting				Spec. Limits:					Units:		
Operator: B. Cornwall					Machine: #11				Gage:					Zero Equals:		
Date: 4/17/2008 1:47:05 PM																
TIME	14:17	14:47	15:17	15:47	16:17	16:47	17:17	17:47	18:17	18:47	19:17	19:47	20:17	20:47	21:17	21:47	22:17
Defect #0	2	8	1	4	0	2	7	6	9	5	2	4	7	0	7	0	1
Defect #1	7	5	1	4	0	3	5	0	5	0	0	5	4	0	2	0	2
Defect #2	0	8	1	0	0	4	5	6	8	3	1	1	3	3	3	1	1
Defect #3	3	8	1	1	1	5	1	1	9	6	1	2	3	4	8	3	1
Defect #4	12	15	2	9	1	12	12	10	15	10	4	11	11	7	13	4	3
FRACT. DEF.	0.240	0.300	0.040	0.180	0.020	0.240	0.240	0.200	0.300	0.200	0.080	0.220	0.220	0.140	0.260	0.080	0.060
NO. INSP.	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50
ALARM	-	H	-	-	-	-	-	-	H	-	-	-	-	-	-	-	-
NOTES	N	Y	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N

The example above uses the ALARM_HIGHLIGHT_TEXT mode

Title: Fraction Defective (p) Chart					Part No.: 321				Chart No.: 19							
Part Name: Left Front Fender					Operation: Painting				Spec. Limits:					Units:		
Operator: B. Cornwall					Machine: #11				Gage:					Zero Equals:		
Date: 4/17/2008 1:49:44 PM																
TIME	5:19	5:49	6:19	6:49	7:19	7:49	8:19	8:49	9:19	9:49	10:19	10:49	11:19	11:49	12:19	12:49	13:19
Defect #0	1	2	2	1	1	2	0	6	2	1	0	7	4	6	2	3	2
Defect #1	5	3	1	2	1	2	0	4	3	0	5	6	3	0	3	5	6
Defect #2	5	4	1	2	1	0	0	3	1	1	3	0	4	5	1	2	5
Defect #3	3	3	9	3	0	8	1	4	5	1	4	1	4	2	4	3	4
Defect #4	8	12	13	6	2	12	1	14	10	2	9	14	9	13	7	13	11
FRACT. DEF.	0.160	0.240	0.260	0.120	0.040	0.240	0.020	0.280	0.200	0.040	0.180	0.280	0.180	0.260	0.140	0.260	0.220
NO. INSP.	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50
ALARM	-	-	-	-	-	-	-	H	-	-	-	H	-	-	-	-	-
NOTES	N	Y	N	N	N	Y	N	N	N	Y	N	N	N	Y	N	N	N

The example above uses the ALARM_HIGHLIGHT_OUTLINE mode. In the table above, the column outlines in blue and red reflect what is actually displayed in the chart, whereas in the other TableAlarmEmphasisMode examples the outline just shows where the alarm highlighting occurs.

The default mode is ALARM_HIGHLIGHT_NONE mode.

AutoLogAlarmsAsNotes

When an alarm occurs, details of the alarm can be automatically logged as a Notes record. Just set the AutoLogAlarmsAsNotes property to true.

[C#]
```
this.AutoLogAlarmsAsNotes = true;
```

[VB]
```
Me.AutoLogAlarmsAsNotes = True
```

Creating a Batch-Based Attribute Control Chart

Both the **SPCTimeAttributeContolChart** and **SPCBatchAttributeControlChart** derive from the **SPCChartBase** and as a result the two classes are very similar and share

95% of all properties in common. Creating and initializing a batch-based SPC chart is much the same as that of a time-based SPC chart. Derive your base class from **SPCBatchAttributeControlChart** class as seen in the **BatchAttributeControlChart.SimpleAttributeControlChart** example program.

[C#]

```
public class SimpleAttributeControlChart:
    com.quinncurtis.spcchartnet.SPCBatchAttributeControlChart
    {
        private System.ComponentModel.IContainer components;
        ChartCalendar startTime = new ChartCalendar();
        int batchCounter = 0;
        //  SPC attribute control chart type
        int charttype = SPCControlChartData.FRACTION_DEFECTIVE_PARTS_CHART;
        // Number of samples per sub group
        int numsamplespersubgroup = 50;
        // Number of defect categories
        int numcategories = 5;
        // Number of data points in the view
        int numdatapointsinview = 17;
        // The time increment between adjacent subgroups
        int timeincrementminutes = 30;

        public SimpleAttributeControlChart()
        {
            // This call is required by the Windows.Forms Form Designer.
            InitializeComponent();
            // Have the chart fill parent client area
            this.Dock = DockStyle.Fill;
            // Define and draw chart
            InitializeChart();
        }

        void InitializeChart()
        {
            // Initialize the SPCBatchAttributeControlChart
            this.InitSPCBatchAttributeControlChart(charttype, numcategories,
                numsamplespersubgroup, numdatapointsinview);
            .
            .
            .
        }
}
```

[VB]

```
Public Class SimpleAttributeControlChart
    Inherits com.quinncurtis.spcchartnet.SPCBatchAttributeControlChart

#Region " Windows Form Designer generated code "
    Public Sub New()
        MyBase.New()

        'This call is required by the Windows Form Designer.
        InitializeComponent()

        'Add any initialization after the InitializeComponent() call
        ' Have the chart fill parent client area
        Me.Dock = DockStyle.Fill
        ' Define and draw chart
        InitializeChart ()
    End Sub

    .
    .
    .

#End Region
```

```
    Dim startTime As New ChartCalendar()
    Dim batchCounter As Integer = 0
    '  SPC attribute control chart type
    Dim charttype As Integer = SPCControlChartData.FRACTION_DEFECTIVE_PARTS_CHART
    ' Number of samples per sub group
    Dim numsamplespersubgroup As Integer = 50
    ' Number of defect categories
    Dim numcategories As Integer = 5
    ' Number of data points in the view
    Dim numdatapointsinview As Integer = 17
    ' The time increment between adjacent subgroups
    Dim timeincrementminutes As Integer = 30


    Sub InitializeChart ()
        ' Initialize the SPCBatchAttributeControlChart
        Me.InitSPCBatchAttributeControlChart(charttype, numcategories, _
           numsamplespersubgroup, numdatapointsinview)
        .
        .
        .
    End Sub 'DrawChart
```

Establish the control chart type (p-, np-, c- or u-chart) using the attribute control charts **InitSPCBatchAttributeControlChart** initialization routine.

SPCBatchAttributeControlChart.InitSPCBatchAttributeControlChart Method

This initialization method initializes the most important values in the creation of a SPC chart.

[VB]

```
Overloads Public Sub InitSPCBatchAttributeControlChart( _
   ByVal charttype As Integer, _
   ByVal numcategories As Integer, _
   ByVal numsamplespersubgroup As Integer, _
   ByVal numdatapointsinview As Integer, _
)
```

[C#]

```
public void InitSPCBatchAttributeControlChart(
   int charttype,
   int numcategories,
   int numsamplespersubgroup,
   int numdatapointsinview,
);
```

Parameters

charttype

Specifies the chart type. Use one of the SPC Attribute Control chart types: PERCENT_DEFECTIVE_PARTS_CHART, FRACTION_DEFECTIVE_PARTS_CHART, NUMBER_DEFECTIVE_PARTS_CHART, NUMBER_DEFECTS_PERUNIT_CHART, NUMBER_DEFECTS_CHART, NUMBER_DEFECTS_PER_MILLION_CHART.

numcategories

In Attribute Control Charts this value represents the number of defect categories used to determine defect counts.

numsamplespersubgroup

In an Attribute Control chart it represents the total sample size per sample subgroup from which the defect data is counted.

numdatapointsinview

Specifies the number of sample subgroups displayed in the graph at one time.

Update the chart data using the **ChartData.AddNewSampleRecord** method, using an override that has the batch number (*batchCounter* below) as the first parameter. Even though a time stamp value is used in the **AddNewSampleRecord** method, it is not used in the actual graph. Instead, it is used as the time stamp for the batch in the table portion of the chart.

[C#]

```
private void SimulateData()
{
    if (this.IsDesignMode) return;
    for (int i=0; i < 200; i++)
    {
        double batchnumber = batchCounter;
        ChartCalendar timestamp = (ChartCalendar) startTime.Clone();
        // Simulate a new sample record
        DoubleArray samples = this.ChartData.SimulateDefectRecord(50 * 0.134,
            SPCControlChartData.PERCENT_DEFECTIVE_PARTS_CHART);
        //  add a new sample record
        this.ChartData.AddNewSampleRecord(batchnumber, timestamp, samples);
        // Simulate timeincrementminutes  minute passing
        startTime.Add(ChartObj.MINUTE, timeincrementminutes);
        batchCounter++;
    }
}
```

[VB]

```
    Private Sub SimulateData() '
      If Me.IsDesignMode Then
          Return
      End If
      Dim i As Integer
      For i = 0 To 199
          Dim group As Double = batchCounter
          Dim timestamp As ChartCalendar = _
              CType(startTime.Clone(), ChartCalendar)
          ' Simulate a new sample record
          Dim samples As DoubleArray = _
              Me.ChartData.SimulateDefectRecord(50 * 0.134, _
              SPCControlChartData.PERCENT_DEFECTIVE_PARTS_CHART)
          '  add a new sample record
          Me.ChartData.AddNewSampleRecord(group, timestamp, samples)
          ' Simulate timeincrementminutes  minute passing
          startTime.Add(ChartObj.MINUTE, timeincrementminutes)
          batchCounter += 1
      Next i
  End Sub 'SimulateData
```

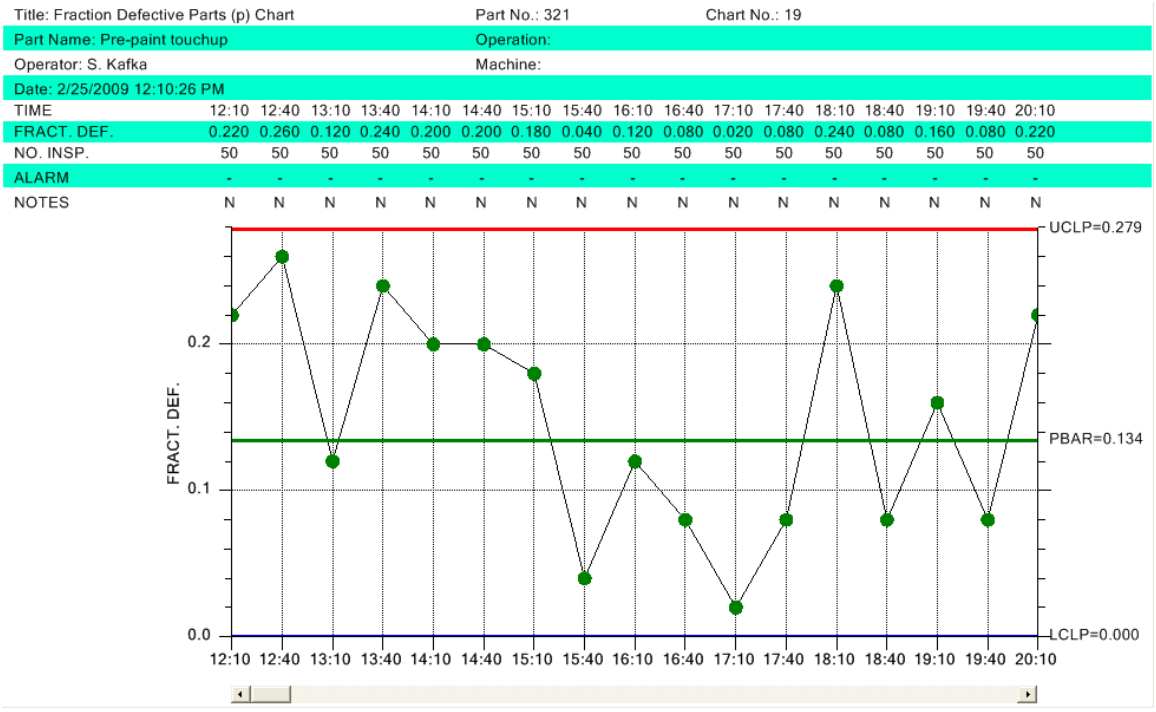
Changing the Batch Control Chart X-Axis Labeling Mode

In revisions prior to 2.0, the x-axis tick marks of a batch control chart could only be labeled with the numeric batch number of the sample subgroup. While batch number labeling is still the default mode, it is now possible to label the sample subgroup tick marks using the time stamp of the sample subgroup, or a user-defined string unique to each sample subgroup.

You may find that labeling every subgroup tick mark with a time stamp, or a user-defined string, causes the axis labels to stagger because there is not enough room to display the tick mark label without overlapping its neighbor. In these cases you may wish to reduce the number of sample subgroups you show on the page using the *numdatapointsinview* variable found in all of the example programs.

```
// Number of datapoints in the view
int numdatapointsinview = 13;
```

Batch Control Chart X-Axis Time Stamp Labeling



Fraction Defective Parts Chart using time stamp labeling of the x-axis

Set the x-axis labeling mode using the overall charts XAxisStringLabelMode property, setting it `SPCChartObjects.AXIS_LABEL_MODE_TIME`.

[C#]

```
// Label the tick mark with time stamp of sample group
this.XAxisStringLabelMode = SPCChartObjects.AXIS_LABEL_MODE_TIME;
```

[VB]

```
' Label the tick mark with time stamp of sample group
Me.XAxisStringLabelMode = SPCChartObjects.AXIS_LABEL_MODE_TIME
```

When updating the chart with sample data, use AddNewSampleRecord overload that has batch number and a time stamp parameters.

[C#]

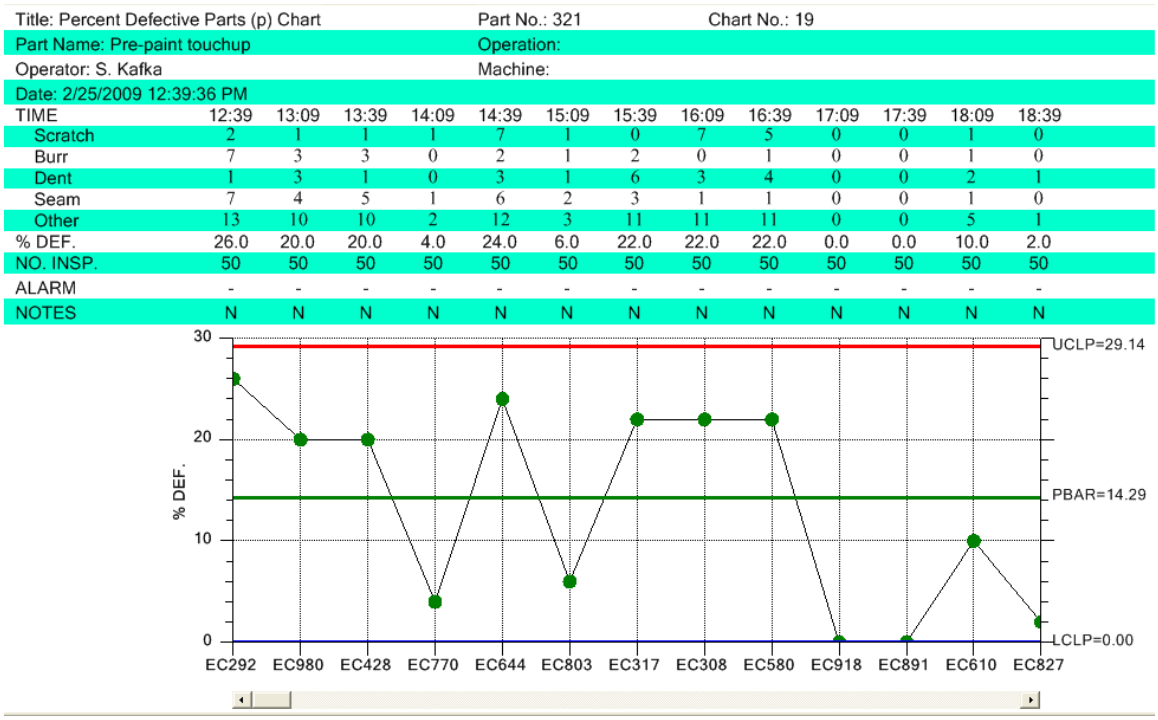
```
this.ChartData.AddNewSampleRecord(batchCounter, timestamp, samples);
```

[VB]

```
Me.ChartData.AddNewSampleRecord(batchCounter, timestamp, samples)
```

See the example program BatchAttributeControlCharts.FractionDefectivePartsControlChart for a complete example. Reset the axis labeling mode back to batch number labeling by assigning the XAxisStringLabelMode property to SPCChartObjects.AXIS_LABEL_MODE_DEFAULT.

Batch Control Chart X-Axis User-Defined String Labeling



Percent Defective Parts Chart using user-defined string labeling of the x-axis

Set the x-axis labeling mode using the overall charts XAxisStringLabelMode property, setting it SPCChartObjects.AXIS_LABEL_MODE_STRING.

[C#]
```
// enable scroll bar
this.EnableScrollBar = true;
this.EnableCategoryValues = false;

// Label the tick mark with user-defined strings
this.XAxisStringLabelMode = SPCChartObjects.AXIS_LABEL_MODE_STRING;
```

[VB]
```
' enable scroll bar
Me.EnableScrollBar = True
Me.EnableCategoryValues = False

' Label the tick mark with user-defined strings
Me.XAxisStringLabelMode = SPCChartObjects. AXIS_LABEL_MODE_STRING
```

Use the AddAxisUserDefinedString method to supply a new string for every new sample subgroup. It must be called every time the AddNewSampleRecord method is called, or the user-defined strings will get out of sync with their respective sample subgroup. Reset the axis labeling mode back to batch number labeling by assigning the XAxisStringLabelMode property to SPCChartObjects.AXIS_LABEL_MODE_DEFAULT.

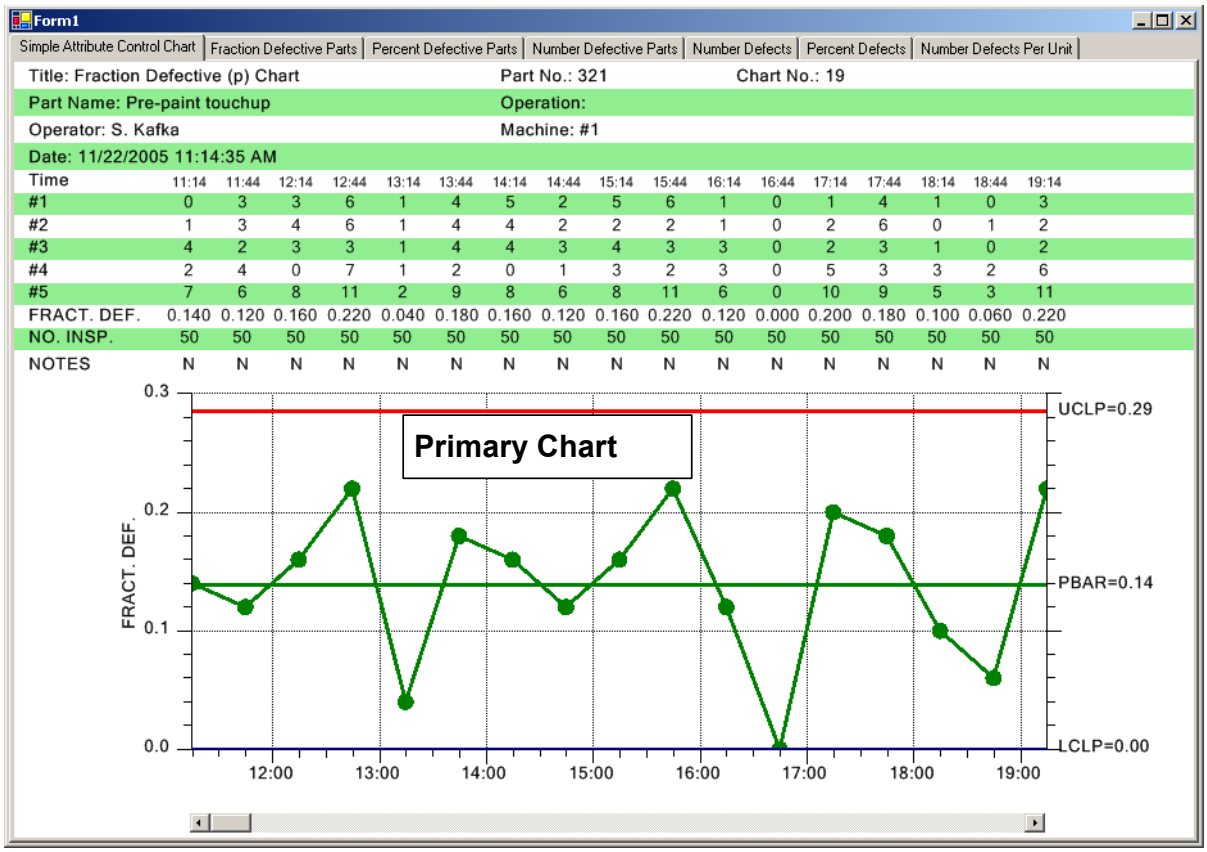
[C#]
```
this.ChartData.AddNewSampleRecord(batchCounter, timestamp, samples,
variableControlLimits);

// Make a random string to simulate some sort of batch sample group ID
int randomnum= (int) (1000 * ChartSupport.GetRandomDouble());
String batchidstring = "EC" + randomnum.ToString();
this.ChartData.AddAxisUserDefinedString(batchidstring);
```

[VB]
```
' Add a new sample record
Me.ChartData.AddNewSampleRecord(batchnumber, timestamp, samples)
Dim randomnum As Integer = CInt((1000 * ChartSupport.GetRandomDouble()))
Dim batchidstring As String = "EC" & randomnum.ToString()
Me.ChartData.AddAxisUserDefinedString(batchidstring)
```

See the example program BatchAttributeControlCharts.PercentDefectivePartsControlChart for a complete example.

Changing Default Characteristics of the Chart

All *Attribute Control Charts* have one distinct graph with its own set of properties. This graph is the Primary Chart.



Logically enough, the properties of the objects that make up each of these graphs are stored in a property named PrimaryChart. Once the graph is initialized (using the **InitSPCTimeAttributeControlChart**, or **InitSPCBatchAttributeControlChart** method), you can modify the default characteristics of each graph using these properties.

```
// Initialize the SPCTimeAttributeControlChart
this.InitSPCTimeAttributeControlChart(charttype, numcategories,
    numsamplespersubgroup, numdatapointsinview, timeincrementminutes);

.
.
.
.

this.GraphStartPosX = 0.2;
// Enable scroll bar
this.EnableScrollBar = true;
this.PrimaryChart.DisplayFrequencyHistogram = true;
this.PrimaryChart.XAxis.LineColor = Color.Blue;
this.PrimaryChart.XAxis.LineWidth = 3;
this.PrimaryChart.ProcessVariableData.LineMarkerPlot.LineAttributes.PrimaryColor =
Color.Black;
this.PrimaryChart.ProcessVariableData.LineMarkerPlot.SymbolAttributes.PrimaryColor
= Color.BlueViolet;
this.PrimaryChart.ProcessVariableData.LineMarkerPlot.SymbolAttributes.FillColor =
Color.Beige;

this.PrimaryChart.GraphBackground.FillColor = Color.LightGray;
this.PrimaryChart.PlotBackground.FillColor = Color.LightGoldenrodYellow;
this.PrimaryChart.FrequencyHistogramChart.PlotBackground.FillColor =
Color.LightGoldenrodYellow;
```

The **PrimaryChart** object is an instance of the **SPCChartObjects** class. The **SPCChartObjects** class contains the objects needed to display a single graph. Below you will find a summary of the class properties.

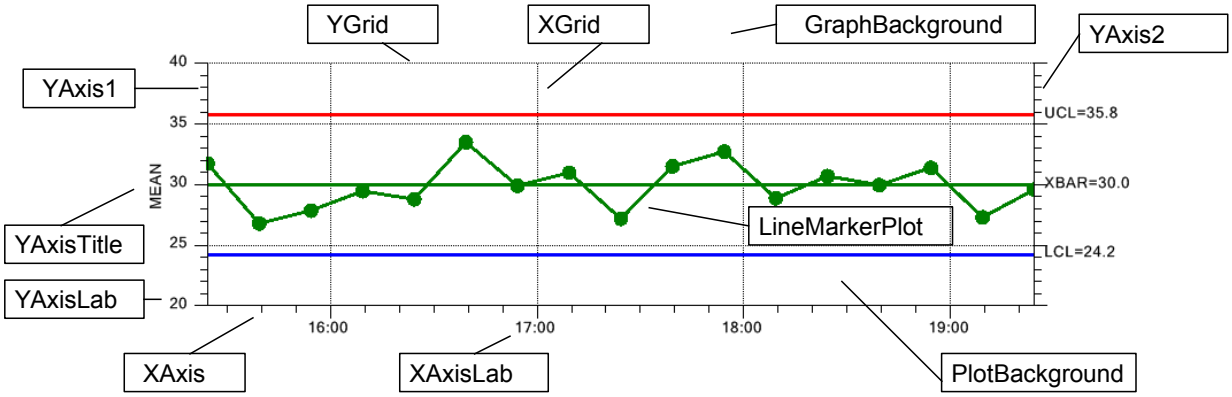
Public Instance Properties

AnnotationArray	Get the array of TextObject objects, representing the annotations of the chart.
AnnotationFont	Set/Get annotation font.
AnnotationNudge	Set/Get the x and y-values use to offset a data points annotation with respect to the actual data point.
AxisLabelFont	Set/Get the font used to label the x- and y-axes.
AxisTitleFont	Set/Get the font used for the axes titles.
ControlLabelPosition	Set/Get that numeric label for a control limit is placed inside, or outside the plot area INSIDE_PLOTAREA.
ControlLimitData	Get the array of the plot objects associated with control limits.
Datatooltip	Get a reference to the charts tooltip.
DefaultChartBackgroundColor	Get/Set the default background color for the graph area.
DefaultNumberControlLimits	Set/Get the number of control limits in the chart.
DefaultPlotBackgroundColor	Get/Set the default background color for the plot area.
DisplayChart	Set to true to enable the drawing of this chart.
DisplayFrequencyHistogram	Set to true to enable the drawing of the frequency histogram attached to the chart.
FrequencyHistogramChart	Get a reference to the optional frequency histogram attached to the chart.
GraphBackground	Get a reference to the charts graph background object.
BatchIncrement	Set/Get increment between adjacent samples of Batch type charts that use a numeric x-scale.
BatchStartValue	Set/Get the starting numeric value of the x-scale for Batch type charts that use a numeric x-scale.
BatchStopValue	Set/Get the ending numeric value of the x-scale for Batch type charts that use a

	numeric x-scale.
Header	Get a reference to the charts header.
HeaderFont	Set/Get the font used for the chart title.
HistogramStartPos	Set/Get the left edge, using normalized coordinates, of the frequency histogram plotting area.
HistogramOffset	Set/Get the offset of the histogram with respect to the GraphStartPosX position, using normalized coordinates, of the frequency histogram plotting area.
MaxY	Set/Get the maximum value used to scale the y-axis of the chart.
MinY	Set/Get the minimum value used to scale the y-axis of the chart.
ParentSPCChartBase	Set/Get that parent SPCChartBase object.
PlotBackground	Get a reference to the charts plot background object.
PlotMeasurementValues	Set to true to enable the plotting of all sampled values, as a scatter plot, in addition to the mean or median values.
PPhysTransform1	Gets a reference to the charts physical coordinate system.
ProcessVariableData	Holds a reference to an object encapsulating the plot object data associated with the main variable of the chart.
SampledDataData	Get the array of the sample data.
SubHead	Get a reference to the charts subhead.
SubheadFont	Set/Get the font used for the chart subhead.
TableFont	Set/Get the font used for the data table.
TextTemplate	Get/Set the text template for the data tooltip.
TimeIncrementMinutes	Get/Set the increment between adjacent samples of charts that use a numeric x-scale.
ToolTipFont	Set/Get tooltip font.
ToolTipSymbol	Get a reference to the charts tooltip symbol.
XAxis	Get a reference to the charts x-axis.
XAxisLab	Get a reference to the charts x-axis labels.
XGrid	Get a reference to the charts x-axis grid.
XValueTemplate	Get/Set the x-value template for the data tooltip.
YAxis1	Get a reference to the charts left y-axis.
YAxis2	Get a reference to the charts right y-axis.
YAxisLab	Get a reference to the charts left y-axis labels.

YAxisTitle	Get a reference to the charts left y-axis title.
YGrid	Get a reference to the charts y-axis grid.
YValueTemplate	Get/Set the y-value template for the data tooltip.

The main objects of the graph are labeled in the graph below.



8. Named and Custom Control Rule Sets

Western Electric (WECO) Rules

The normal SPC control limit rules display at the 3-sigma level, both high and low. In this case, a simple threshold test determines if a process is in, or out of control. Once a process is brought under control using the simple 3-sigma level tests, quality engineers often want to increase the sensitivity of the control chart, detecting and correcting problems before the 3-sigma control limits are reached. Other, more complex tests rely on more complicated decision-making criteria. These rules utilize historical data and look for a non-random pattern that can signify that the process is out of control, before reaching the normal +-3 sigma limits. The most popular of these are the Western Electric Rules, also know as the WECO Rules, or WE Runtime Rules. First implemented by the Western Electric Co. in the 1920's, these quality control guidelines were codified in the 1950's and form the basis for all of the other rule sets. Different industries across the globe have have developed their own variants on the WECO Rules. Other sets of rules, common enough to have an identifying name, i.e. *named rules*, are listed below.

WECO Runtime and Supplemental Rules – Western Electric Co. - Western Electric Company (1956), *Statistical Quality Control handbook.* (1 ed.), Indianapolis, Indiana: Western Electric Co., p. v, OCLC 33858387. Sometimes the Supplemental Rules are referred to as the Montgomery Rules, after the statistical quality control expert Douglas Mongtomery. *Introduction to Statistical Quality Control* (5 ed.), Hoboken, New Jersey: John Wiley & Sons, ISBN 9780471656319

Nelson Rules – The Nelson rules were first published in the October 1984 issue of the Journal of Quality Technology in an article by Lloyd S Nelson.

AIAG Rules– The (AIAG) Automotive Industry Action Group control rules are published in the their industry group "Statistical Process Control Handbook".

Juran Rules - Joseph M. Juran was an international expert in quality control and defined these rules in his "Juran's Quality Handbook", McGraw-Hill Professional; 6 edition (May 19, 2010), **ISBN-10:** 0071629734

Hughes Rules – The only sources we could find for the Hughes rules were all second hand. If anyone can direct is to an original source for the Hughes Rules, please send an e-mail to support@quinn-curtis.com.

Duncan Rules – Acheson Johnston Duncan was an international expert in quality control and published his rules in the text book "Quality control and industrial statistics" (fifth edition). Irwin, 1986.

Gitlow Rules - Dr. Howard S. Gitlow is an international expert in Sigma Six, TQM and SPC. His rules are found in his book "Tools and Methods for the Improvement of Quality", 1989, **ISBN-10: 0256056803** .

Westgard Rules – The Westgard rules are based on the work of James Westgard, a leading expert in laboratory quality management . They are considered "Laboratory quality control rules". You can find more information about the Westgard Rules, and James Westgard at the web site: http://www.westgard.com

The rules sets have many individual rules in common. In particular, the WECO rules and the Nelson rules, have 7 out of 8 rules in common, and only differ in the fourth rule.

Western Electric (WECO) Rules

In the Western Electric Rules A process is considered out of control if any of the following criteria are met:

1. **The most recent point plots outside one of the 3-sigma control limits.** If a point lies outside either of these limits, there is only a 0.3% chance that this was caused by the normal process.

2. **Two of the three most recent points plot outside and on the same side as one of the 2-sigma control limits.** The probability that any point will fall outside the warning limit is only 5%. The chances that two out of three points in a row fall outside the warning limit is only about 1%.

3. **Four of the five most recent points plot outside and on the same side as one of the 1-sigma control limits.** In normal processing, 68% of points fall within one sigma of the mean, and 32% fall outside it. The probability that 4 of 5 points fall outside of one sigma is only about 3%.

4. **Eight out of the last eight points plot on the same side of the center line, or target value.** Sometimes you see this as 9 out of 9, or 7 out of 7. There is an equal chance that any given point will fall above or below the mean. The chances that a point falls on the same side of the mean as the one before it is one in two. The odds that the next point will also fall on the same side of the mean is one in four. The probability of getting eight points on the same side of the mean is only around 1%.

These rules apply to both sides of the center line at a time. Therefore, there are eight actual alarm conditions: four for the above center line sigma levels and four for the below center line sigma levels.

There are also additional WE Rules for trending. These are often referred to as WE Supplemental Rules. Don't rely on the rule number, often these are listed in a different order.

5. **Six points in a row increasing or decreasing.** The same logic is used here as for rule 4 above. Sometimes this rule is changed to seven points rising or falling.

6. **Fifteen points in a row within one sigma.** In normal operation, 68% of points will fall within one sigma of the mean. The probability that 15 points in a row will do so, is less than 1%.

7. **Fourteen points in a row alternating direction.** The chances that the second point is always higher than (or always lower than) the preceding point, for all seven pairs is only about 1%.

8. **Eight points in a row outside one sigma.** Since 68% of points lie within one sigma of the mean, the probability that eight points in a row fall outside of the one-sigma line is less than 1%.

The rules are described as they appear in the literature. In many cases, a given rule actually specifies two test conditions; the first being a value N out of M above a plus sigma control limit, and the second being a value N out of M below a minus sigma control limit. Examples of this are rules #1, #2 and #3 for WECO and Nelson rules. In other cases, similar rules only contain one test case; N out of M above (or below) a given sigma control limit. Example of this are the Juran rules #2..#5, Hughes Rules #2..#9, Gitlow Rules #2..#5, and Duncan Rules #2..#5.

While the list of named rules below follow what is presented in the literature, the actual rule numbering should be ignored. That is because in the software we implement all rules as simple single condition rules. The first rule in all of the named rule sets is implemented as two rules; a single point greater than 3-sigma; and a single point less than -3-sigma. And WECO and Nelson rules #2 and #3 are implemented as four rules; two N out of M greater than x-sigma condition limits, and two N out of M less than x-sigma condition limits. A complete cross reference to the named rules listed below, and our own rule number system is found in Table 1. This is important, because when you try to access a particular named rule within the software, you must use our rule number system.

Basic Rules

The Basic Rules are the default rules for all of the SPC charts. They correspond to the +-3-sigma rules used by almost every industry standard SPC chart implementation.

1. One of one point is outside of +-3-sigma control limits

Nelson Rules

The Nelson rules are almost identical to the combination of the WECO Runtime and Supplemental Rules. The only difference is in Rule #4.

4. Nine out of the last nine points plot on the same side of the center line, or target value.

AIAG Rules

1. One of one point is outside of +-3-sigma control limits
2. Seven out of seven are above or below center line
3. Seven points in a row increasing
4. Seven points in a row decreasing

Juran Rules

1. One of one point is outside of +- 3-sigma control limits
2. Two of three points above 2-sigma control limits
3. Two of three points below -2-sigma control limits
4. Four of five points is above 1-sigma control limits
5. Four of five points is below -1-sigma control limit s
6. Six points in a row increasing
7. Six points in a row decreasing
8. Nine out of nine are above or below center line
9. Eight points in a row on both sides of center line, none in zone C

Hughes Rules

1. One of one point is outside of +- 3-sigma control limits
2. Two of three points above 2-sigma control limits
3. Two of three points below -2-sigma control limit s
4. Three of seven points above 2-sigma control limits
5. Three of seven points below -2-sigma control limit s
6. Four of ten points above 2-sigma control limits
7. Four of ten points below -2-sigma control limits
8. Four of five points is above 1-sigma control limits
9. Four of five points is below -1-sigma control limits
10. Seven points in a row increasing
11. Seven points in a row decreasing
12. Ten of eleven are above center line
13. Ten of eleven are below center line
14. Twelve of fourteen are above center line
15. Twelve of fourteen are below center line

Gitlow Rules

1. One of one point is outside of +- 3-sigma control limits
2. Two of three points above 2-sigma control limits
3. Two of three points below -2-sigma control limits
4. Four of five points is above 1-sigma control limits
5. Four of five points is below -1-sigma control limits
6. Eight points in a row increasing
7. Eight points in a row decreasing
8. Eight out of Eight are above center line

9. Eight out of Eight are below center line

Duncan Rules

1. One of one point is outside of +- 3-sigma control limits
2. Two of three points above 2-sigma control limits
3. Two of three points below -2-sigma control limits
4. Four of five points is above 1-sigma control limits
5. Four of five points is below -1-sigma control limits
6. Seven points in a row increasing
7. Seven points in a row decreasing

Westgard Rules

1. One of one point is outside of +- 3-sigma control limits - 13s
2. Two of two points outside +-2-sigma control limits - 22s
3. Four of four points outside +-1-sigma control limits - 41s
4. Ten of ten points on one side of center line - 10x
5. Two adjacent points on opposite sides of +-2-sigma - R4s
6. Seven of seven points in a trend increasing or decreasing - 7T
7. One of one point is outside of +- 2-sigma control limits – 12s
8. Two of three points outside +-2-sigma control limits - 2of32s
9. Three of three points outside +-1-sigma control limits - 31s
10. Six of six points on one side of center line - 6x
11. Eight of eight points on one side of center line - 8x
12. Nine of nine points on one side of center line - 9x
13. Twelve of twelve points on one side of center line – 12x

By default, only the first six Westgard rules described above are enabled. The others can be turned on using the **UseNamedRuleSet** method and setting *ruleflags* array elements true for the additional rules. Make sure you use our rule numbers and not the rule numbering above.

Control Rule Templates

All of the named rules fall into one of our standard rule categories. Each rule category is a flexible template which can be used to evaluate a test condition across a wide range of parameters. A list of the template categories appears below.

Standardized Templates for Control Rule Evaluation

Template #	
	Standard Control Limit tests
1	N of M above X sigma (from center line), used for UCL tests
2	N of M below X sigma (from center line), used for LCL tests
3	Reserved
4	N of M beyond X sigma (from center line, either side) or control limits – points beyond the +- limit values – don't have to all be on one side
	Trending
5	N of M trending up (increasing)
6	N of M trending down (decreasing)
7	N of M trending up (increasing) or down (decreasing)
	Hugging (lack of variance)
8	N of M within X sigma (from center line, either side)
9	N ofr M within X sigma of each other (no reference to center line)
	Oscillation
10	N of M alternating about X sigma (from center line)
11	N of M alternating (no reference to center line)

For example, rule #1 for all of the named rules (a single point plots outside of +- 3 sigma) is implemented as one instance of template #1 (N of M above X sigma, where N=1, M=1 and X = 3) and one instance of template #2 (N of M below X sigma) where N=1, M=1 and X = -3).

Rule #2 for WECO and Nelson (two of three point plots outside of +- 2 sigma) is implemented as one instance of template #1 (N of M above X sigma, where N=2, M=3 and X = 2) and one instance of template #2 (N of M below X sigma) where N=2, M=3 and X = -2).

Rule #4 and #5 for Hughes (three of seven points above/below 2-sigma control limit) is implemented as one instance of template #1 (N of M above X sigma, where N=3, M=7 and X = 2) and one instance of template #2 (N of M below X sigma) where N=3, M=7 and X = -2).

Rule #6 for Gitlow (eight points in a row increasing) is implemented as one instance of template #5 (N of M trending up) where N=8 and M=8.

The templates are important because using them you can modify any existing named rule, changing the M, N or X parameter. Or, you can create completely new rules.

Taking these factors into account, we have redefined and renumbered the rules, identifying each with the template and parameters used by each rule, .

Standardized Template Parameters and Rule # Cross Reference for Named Rules

Basic Rules			New			
Rule #	**Description**	**Rule #**	**Template #**	**N of**	**M**	**X**
#1	1 of 1 < 3 sigma	1	1	1	1	-3
	1 of 1 > 3 sigma	2	2	1	1	3

WECO		New				
Rule #	**Description**	**Rule #**	**Template #**	**N of**	**M**	**X**
#1	1 of 1 < 3 sigma	1	1	1	1	-3
	1 of 1 > 3 sigma	2	2	1	1	3
#2	2 of 3 < 2 sigma	3	1	2	3	-2
	2 of 3 > 2 sigma	4	2	2	3	2
#3	4 of 5 < sigma	5	1	4	5	-1
	4 of 5 > sigma	6	2	4	5	1
#4	8 of 8 < center line	7	1	8	8	0
	8 of 8 > center line	8	2	8	8	0

WECO+Supplemental		New				
Rule #	**Description**	**Rule #**	**Template #**	**N of**	**M**	**X**
#1	1 of 1 < 3 sigma	1	1	1	1	-3
	1 of 1 > 3 sigma	2	2	1	1	3
#2	2 of 3 < 2 sigma	3	1	2	3	-2
	2 of 3 > 2 sigma	4	2	2	3	2
#3	4 of 5 < sigma	5	1	4	5	-1
	4 of 5 > sigma	6	2	4	5	1
#4	8 of 8 < center line	7	1	8	8	0
	8 of 8 > center line	8	2	8	8	0
#5	6 of 6 incr. or dec.	9	7	6	6	0
#6	15 of 15 within 1 sigma	10	8	15	15	1
#7	14 of 14 alternating	11	11	14	14	0
#8	8 of 8 outside zone C	12	4	8	8	1

Nelson		New				
Rule #	**Description**	**Rule #**	**Template #**	**N of**	**M**	**X**
#1	1 of 1 < 3 sigma	1	1	1	1	-3
	1 of 1 > 3 sigma	2	2	1	1	3
#2	2 of 3 < 2 sigma	3	1	2	3	-2
	2 of 3 > 2 sigma	4	2	2	3	2
#3	4 of 5 < sigma	5	1	4	5	-1

	4 of 5 > sigma	6	2	4	5	1
#4	9 of 9 < center line	7	1	9	9	0
	9 of 9 > center line	8	2	9	9	0
#5	6 of 6 incr. or dec.	9	7	6	6	0
#6	15 of 15 within 1 sigma	10	8	15	15	1
#7	14 of 14 alternating	11	11	14	14	0
#8	8 points outside zone C	12	4	8	8	1

AIAG

Rule #	Description	New Rule #	Template #	N of	M	X
#1	1 of 1 < 3 sigma	1	1	1	1	-3
	1 of 1 > 3 sigma	2	2	1	1	3
#2	7 of 7 < center line	3	1	7	7	0
#3	7 of 7 > center line	4	2	7	7	0
#4	7 of 7 increasing	5	5	7	7	0
#5	7 of 7 decreasing	6	6	7	7	0

Juran

Rule #	Description	New Rule #	Template #	N of	M	X
#1	1 of 1 < 3 sigma	1	1	1	1	-3
	1 of 1 > 3 sigma	2	2	1	1	3
#2	2 of 3 < 2 sigma	3	1	2	3	-2
#3	2 of 3 > 2 sigma	4	2	2	3	2
#4	4 of 5 < sigma	5	1	4	5	-1
#5	4 of 5 > sigma	6	2	4	5	1
#6	6 of 6 increasing	7	5	6	6	0
#7	6 of 6 decreasing	8	6	6	6	0
#8	9 of 9 > center line	9	1	9	9	0
#9	9 of 9 < center line	10	2	9	9	0
#10	8 of 8 outside zone C	11	4	8	8	1

Hughes

Rule #	Description	New Rule #	Template #	N of	M	X
#1	1 of 1 < 3 sigma	1	1	1	1	-3
	1 of 1 > 3 sigma	2	2	1	1	3
#2	2 of 3 < 2 sigma	3	1	2	3	-2
#3	2 of 3 > 2 sigma	4	2	2	3	2
#4	3 of 7 < 2 sigma	5	1	3	7	-2
#5	3 of 7 > 2 sigma	6	2	3	7	2
#6	4 of 10 < 2 sigma	7	1	4	10	-2
#7	4 of 10 > 2 sigma	8	2	4	10	2
#8	4 of 5 < sigma	9	1	4	5	-1
#9	4 of 5 > sigma	10	2	4	5	1
#10	7 of 7 increasing	11	5	7	7	0

#11	7 of 7 decreasing	12	6	7	7	0
#12	10 of 11 < center line	13	1	10	11	0
#13	10 of 11 > center line	14	2	10	11	0
#14	12 of 14 < center line	15	1	12	14	0
#15	12 of 14 > center line	16	2	12	14	0

Gitlow Rule #	**Description**	**New Rule #**	**Template #**	**N of**	**M**	**X**
#1	1 of 1 < 3 sigma	1	1	1	1	-3
	1 of 1 > 3 sigma	2	2	1	1	3
#2	2 of 3 < 2 sigma	3	1	2	3	-2
#3	2 of 3 > 2 sigma	4	2	2	3	2
#4	4 of 5 < sigma	5	1	4	5	-1
#5	4 of 5 > sigma	6	2	4	5	1
#6	8 of 8 increasing	7	5	8	8	0
#7	8 of 8 decreasing	8	6	8	8	0
#8	8 of 8 < center line	9	1	8	8	0
#9	8 of 8 > center line	10	2	8	8	0

Duncan Rule #	**Description**	**New Rule #**	**Template #**	**N of**	**M**	**X**
#1	1 of 1 < 3 sigma	1	1	1	1	-3
	1 of 1 > 3 sigma	2	2	1	1	3
#2	2 of 3 < 2 sigma	3	1	2	3	-2
#3	2 of 3 > 2 sigma	4	2	2	3	2
#4	4 of 5 < sigma	5	1	4	5	-1
#5	4 of 5 > sigma	6	2	4	5	1
#6	7 of 7 increasing	7	5	7	7	0
#7	7 of 7 decreasing	8	6	7	7	0

Westgard Rule #	**Description**	**New Rule #**	**Template #**	**N of**	**M**	**X**
1	1 of 1 < 3 sigma	1	1	1	1	-3
	1 of 1 > 3 sigma	2	2	1	1	3
2	2 of 2 < 2 sigma	3	1	2	2	-2
	2 of 2 > 2 sigma	4	2	2	2	2
3	4 of 4 < 1 sigma	5	1	4	4	-1
	4 of 4 > 1 sigma	6	2	4	4	1
4	10 of 10 < centerline	7	1	10	10	0
	10 of 10 > centerline	8	2	10	10	0
5	R2s – 2-sigma limits	9	10	1	1	2
6	7 of 7 trending	10	7	7	7	0

7	1 of 1 > 2 sigma	11	1	1	1	-2
	1 of 1 < 2 sigma	12	2	1	1	2
8	2 of 3 > 3 sigma	13	1	2	3	-2
	2 of 3 < 3 sigma	14	2	2	3	2
9	3 of 3 > 1 sigma	15	1	3	3	-1
	3 of 3 < 1 sigma	16	2	3	3	1
10	6 of 6 < centerline	17	1	6	6	0
	6 of 6 > centerline	18	2	6	6	0
11	8 of 8 < centerline	19	1	8	8	0
	8 of 8 > centerline	20	2	8	8	0
12	9 of 9 < centerline	21	1	9	9	0
	9 of 9 > centerline	22	2	9	9	0
13	12 of 12 < centerline	23	1	12	12	0
	12 of 12 > centerline	24	2	12	12	0

Implementing a Named Rule Set

You are able to add a named rule set to an SPC application using a single call. Call the **UseNamedRuleSet** method, passing in the appropriate rule ID.

SPCChartObjects.UseNamedRuleSet Method

Visual Basic (Declaration)

```
Public Sub UseNamedRuleSet ( _
        ruleset As Integer _
)
```

```
Public Sub UseNamedRuleSet ( _
        ruleset As Integer, _
        ruleflags As BoolArray _
_
)
```

C#

```
public void UseNamedRuleSet(
        int ruleset
)
```

```
public void UseNamedRuleSet(
        int ruleset,
```

```
        BoolArray ruleflags
)
```

Parameters

ruleset

Type: System..::.Int32

One of the SPCControlLimitRecord named rule indentifiers: BASIC_RULES, WECO_RULES,WECOANDSUPP_RULES, NELSON_RULES,AIAG_RULES, JURAN_RULES, HUGHES_RULES,GITLOW_RULES, WESTGARD_RULES, and DUNCAN_RULES.

ruleflags

Type: com.quinncurtis.chart2dnet..::.BoolArray

An array of bool, one for each named rule in the rule set. ///

[C#]

```
// Use the standard +-3-sigma control limits. Equivalent to WECO control rules #1 and #2.
this.PrimaryChart.UseNamedRuleSet(SPCControlLimitRecord.BASIC_RULES);

// Use the WECO rules.  This corresponds WECO rules #1... #4, which in our organization of the
rules is #1 to #8
this.PrimaryChart.UseNamedRuleSet(SPCControlLimitRecord.WECO_RULES);

// Use the WECO rules.  This corresponds WECO rules #1... #8 , which in our organization of the
rules is #1 to #12
this.PrimaryChart.UseNamedRuleSet(SPCControlLimitRecord.WECOANDSUPP_RULES);

// Use the complete set of Nelson rules.
this.PrimaryChart.UseNamedRuleSet(SPCControlLimitRecord.NELSON_RULES);

// Use the complete set of AIAG rules.
this.PrimaryChart.UseNamedRuleSet(SPCControlLimitRecord.AIAG_RULES);

// Use the complete set of Juran rules.
this.PrimaryChart.UseNamedRuleSet(SPCControlLimitRecord.JURAN_RULES);

// Use the complete set of Hughes rules.
this.PrimaryChart.UseNamedRuleSet(SPCControlLimitRecord.HUGHES_RULES);


// Use the complete set of Gitlow rules.
this.PrimaryChart.UseNamedRuleSet(SPCControlLimitRecord.GITLOW_RULES);

// Use the complete set of Westgard rules.
this.PrimaryChart.UseNamedRuleSet(SPCControlLimitRecord.WESTGARD_RULES);

// Use the complete set of Duncan rules.
this.PrimaryChart.UseNamedRuleSet(SPCControlLimitRecord.DUNCAN_RULES);
```

[VB]

```
' Use the standard +-3-sigma control limits. Equivalent to WECO control rules #1 and #2.
```

```
Me.PrimaryChart.UseNamedRuleSet(SPCControlLimitRecord.BASIC_RULES)

' Use the WECO rules.  This corresponds WECO rules #1... #4, which in our organization of the
rules is #1 to #8
Me.PrimaryChart.UseNamedRuleSet(SPCControlLimitRecord.WECO_RULES)
.
.
.
' Use the complete set of Duncan rules.
Me.PrimaryChart.UseNamedRuleSet(SPCControlLimitRecord.DUNCAN_RULES)
```

The named rule setup methods also come in variants which allow you to selectively enable/diasble one or more rules from the named rule set. You do that by building a BoolArray object, containing true or false for each named rule in the rule set, and calling **UseNamedRuleSet** method. The **GetInitializedRuleBoolArray** is just a simple utility method which creates and fills out an appropriately sized BoolArray array with a default true, or false value.

SPCChartObjects.GetInitializedRuleBoolArray Method

Visual Basic (Declaration)

```
Public Function GetInitializedRuleBoolArray ( _
        ruleset As Integer, _
        initialvalue As Boolean _
) As BoolArray
```

C#

```
public BoolArray GetInitializedRuleBoolArray(
        int ruleset,
        bool initialvalue
)
```

Parameters

ruleset

Type: System..::.Int32
One of the SPCControlLimitRecord named rule identifiers: BASIC_RULES, WECO_RULES,WECOANDSUPP_RULES, NELSON_RULES,AIAG_RULES, JURAN_RULES, HUGHES_RULES,GITLOW_RULES, WESTGARD_RULES, and DUNCAN_RULES.

initialvalue

Type: System..::.Boolean
True or False, all values of the returned BoolArray are initialized to this value.

*All rule numbering is based on our rule numbering, which separates greater than and less than tests into separate rules, as detailed in the previous tables.

[C#]

```
BoolArray ruleflags = this.PrimaryChart.GetInitializedRuleBoolArray(
    SPCControlLimitRecord.NELSON_RULES, true);
ruleflags[9] = false;
ruleflags[10] = false;
this.PrimaryChart.UseNamedRuleSet(SPCControlLimitRecord.NELSON_RULES , ruleflags);
```

[VB]

```
Dim ruleflags As BoolArray =
    Me.PrimaryChart.GetInitializedRuleBoolArray(SPCControlLimitRecord.NELSON_RULES, True)
  ruleflags(9) = False
  ruleflags(10) = False

 Me.PrimaryChart.UseNamedRuleSet(SPCControlLimitRecord.NELSON_RULES)
```

The example above disables rule #9 (6 of 6 increasing or decreasing) and rule #10 (15 of 15 within 1 sigma) from the Nelson Rules. You use our rule numbering system for specifying which rule.

See the example program RulesRulesRules for examples of how to setup an SPC chart for a given set of control rules. Once you add a set of named control rules to your SPC chart, the next thing you will want to do is set the control limits. You can either set the limits using known values, or you can have our software calculate the limits using previously acquired sample data.

If you want to explicitly set the limits you must know the historical process mean (also called the center line) and the historical process sigma. You may already know your process sigma, or you may need to calculate it as 1/3 * (UCL – process mean), where UCL is your historical +3-sigma upper control limit. Once you have those two values, everything else is automatic. Just call the **UpdateControlLimitUsingMeanAndSigma** method. It will run through all of the control limit records and fill out the appropriate limit values and other critical parameters.

SPCControlChartData.UpdateControlLimitsUsingMeanAndSigma Method

Visual Basic (Declaration)

```
Public Sub UpdateControlLimitsUsingMeanAndSigma ( _
        chartpos As Integer, _
        mean As Double, _
        sigma As Double _
)
```

C#

```
public void UpdateControlLimitsUsingMeanAndSigma(
        int chartpos,
        double mean,
        double sigma
)
```

Parameters

chartpos

Type: System..::.Int32
specifiy either SPC_PRIMARY_CONTROL_TARGET or SPC_SECONDARY_CONTROL_TARGET

mean

Type: System..::.Double
specify the process mean.

sigma

Type: System..::.Double
specify the process sigma.

```
double processMean = your process mean
double processSigma = your process sigma
this.ChartData.UpdateControlLimitsUsingMeanAndSigma(SPCChartObjects.PRIMARY_CHART,
    processMean, processSigma);
```

The center line value and sigma have different meanings for the Primary and Secondary charts. So the **UpdateControlLimitsUsingMean** and Sigma applies to only one at a time. If you use it for the secondary chart control limits, use your historical center line value for the secondary chart type you are using. Calculate the sigma value as 1/3 * (UCL – center line), where UCL is your historical +3-sigma upper control limit for your secondary chart.

You can also auto-calculate the control limits by adding test data to your application (fed into the chart using the **AddNewSampleRecord** method), and calling **AutoCalculatedControlLimits.** This fills out the **SPCControlLimit** record for each control rule of the named rule set and makes control limit checking possible. You will find the AutoCalculateControlLimits method used in all of SPC charts of the RulesRulesRules example program.

[C#]

```
this.PrimaryChart.UseNamedRuleSet(SPCControlLimitRecord.WECO_RULES);

// Must have data loaded before any of the Auto.. methods are called
 SimulateData(100, 20);

// Calculate the SPC control limits for both graphs of the current SPC chart
this.AutoCalculateControlLimits();
```

[VB]

```
Me.PrimaryChart.UseNamedRuleSet(SPCControlLimitRecord.WECO_RULES)

' Must have data loaded before any of the Auto.. methods are called
 SimulateData(100, 20)

' Calculate the SPC control limits for both graphs of the current SPC chart
Me.AutoCalculateControlLimits()
```

Modifying Existing Named Rules

Perhaps you like everything about a named rule set, except for one or more rules. For example, you want to use the Hughes rules, but want to change the N of M parameters of rules #15 and #16. You do that using the **SPCControlLimitRecord** method **SetCustomRuleParameters**.

SPCControlLimitRecord.SetCustomRuleParameters Method

Visual Basic (Declaration)

```
Public Sub SetCustomRuleParameters ( _
        valuesincalc As Integer, _
        numvaluesforruleviolation As Integer _
)
```

C#

```
public void SetCustomRuleParameters(
        int valuesincalc,
        int numvaluesforruleviolation
)
```

C#

```
public void SetCustomRuleParameters(
        int valuesincalc,
        int numvaluesforruleviolation
)
```

Parameters

valuesincalc

Type: System..::.Int32

Specifies the number of values to use in calculation.

numvaluesforruleviolation

Type: System..::.Int32

Specifies the number of values that must be outside alarm limit for rule violation.

The example below changes the N of M parameters of Hughes rules #15 and #16 from their default N of M value (12 of 14), to the values (15 of 18).

[C#]

```
this.PrimaryChart.UseNamedRuleSet(SPCControlLimitRecord.HUGHES_RULES);

int M = 18;
int N = 15;
SPCControlLimitRecord clr =
     this.ChartData.GetNamedControlRuleRecord(SPCControlLimitRecord.HUGHES_RULES, 15);
clr.SetCustomRuleParameters(M, N);
clr = this.ChartData.GetNamedControlRuleRecord(SPCControlLimitRecord.HUGHES_RULES, 16);
clr.SetCustomRuleParameters(M, N);
```

[VB]

```
Me.PrimaryChart.UseNamedRuleSet(SPCControlLimitRecord.HUGHES_RULES)

Dim M As Integer = 18
Dim N As Integer = 15
Dim clr As SPCControlLimitRecord =
   Me.ChartData.GetNamedControlRuleRecord(SPCControlLimitRecord.HUGHES_RULES, 15)
clr.SetCustomRuleParameters(M, N)
clr = Me.ChartData.GetNamedControlRuleRecord(SPCControlLimitRecord.HUGHES_RULES, 16)
clr.SetCustomRuleParameters(M, N)
```

When trying to access the **SPCControlLimitRecord** for a given control rule, it is very important that you use the **GetNamedControlRuleRecord** method, not the **GetControlLimitRecord** method. This is because the array indexing of the **ControlLimitRecords** does not match the named control rule numbering, i.e., **GetNamedControlRuleRecord**(15) and **GetControlLimitRecord**(15) return different SPCControlLimitRecords.

If you want to enable/disable a specific rule, after they have all been created,

[C#]

```
SPCControlLimitRecord clr =
        this.ChartData.GetNamedControlRuleRecord(SPCControlLimitRecord.AIAG_RULES, 3);
clr.AlarmEnable = false;
```

[VB]

```
SPCControlLimitRecord clr =
        Me.ChartData.GetNamedControlRuleRecord(SPCControlLimitRecord.AIAG_RULES, 3)
clr.AlarmEnable = false
```

Creating Custom Rules Sets Based on Named Rules

You can create your own custom set of rules, mixing and matching rules from the standard, named rule sets, using the the **AddControlRule** method. Also, you can invent your own rules, based on one of our standard templates, and add those rules to your custom rule set.

SPCChartObjects.AddControlRule Method

Visual Basic (Declaration)

```
Public Function AddControlRule ( _
        ruleset As Integer, _
        rulenum As Integer _
) As Integer
```

C#

```
public int AddControlRule(
        int ruleset,
        int rulenum
)
```

Parameters

ruleset

Type: System..::.Int32
One of the SPCControlLimitRecord named rule indentifiers: BASIC_RULES, WECO_RULES,WECOANDSUPP_RULES, NELSON_RULES,AIAG_RULES, JURAN_RULES, HUGHES_RULES,GITLOW_RULES, WESTGARD_RULES, and DUNCAN_RULES.

rulenum

Type: System..::.Int32
The rule number (our rule number) ///

Even if you do not call one of the **Use..Rules** methods, you still end up with four control limits. These correspond to the +-3-sigma control limits, for both the Primary and Secondary (were applicable) chart. So, you do not need to add those to your custom set of rules. Start with the rules you want to add after the standard +-3-sigma rules. If, for some reason you cannot live with the default +-3-sigma rules, you can disable them with a call to **EnableDefaultLimits**(false, false).

Say you want to create custom rule set for the Primary chart, combining rules from Nelson (#3, #4), Juran (#5, #5), AIAG (#3,#4), Hughes (#12) and Duncan (#8). Make the following calls in the setup portion of your program.

[C#]

```
this.PrimaryChart.AddControlRule(SPCControlLimitRecord.NELSON_RULES, 3);
this.PrimaryChart.AddControlRule(SPCControlLimitRecord.NELSON_RULES, 4);
this.PrimaryChart.AddControlRule(SPCControlLimitRecord.JURAN_RULES, 5);
this.PrimaryChart.AddControlRule(SPCControlLimitRecord.JURAN_RULES, 6);
this.PrimaryChart.AddControlRule(SPCControlLimitRecord.AIAG_RULES, 3);
this.PrimaryChart.AddControlRule(SPCControlLimitRecord.AIAG_RULES, 4);
this.PrimaryChart.AddControlRule(SPCControlLimitRecord.HUGHES_RULES, 12);
this.PrimaryChart.AddControlRule(SPCControlLimitRecord.DUNCAN_RULES, 8);
```

[VB]

```
Me.PrimaryChart.EnableDefaultLimits(False, False)
Me.PrimaryChart.AddControlRule(SPCControlLimitRecord.WECO_RULES, 1)
Me.PrimaryChart.AddControlRule(SPCControlLimitRecord.WECO_RULES, 2)
Me.PrimaryChart.AddControlRule(SPCControlLimitRecord.NELSON_RULES, 3)
Me.PrimaryChart.AddControlRule(SPCControlLimitRecord.NELSON_RULES, 4)
Me.PrimaryChart.AddControlRule(SPCControlLimitRecord.JURAN_RULES, 5)
Me.PrimaryChart.AddControlRule(SPCControlLimitRecord.JURAN_RULES, 6)
Me.PrimaryChart.AddControlRule(SPCControlLimitRecord.AIAG_RULES, 3)
Me.PrimaryChart.AddControlRule(SPCControlLimitRecord.AIAG_RULES, 4)
Me.PrimaryChart.AddControlRule(SPCControlLimitRecord.HUGHES_RULES, 12)
Me.PrimaryChart.AddControlRule(SPCControlLimitRecord.DUNCAN_RULES, 8)
```

Normally there will be no reason to set custom rules for the secondary chart, since all of the named rules apply to the Primary chart. Nothing stops you from doing it though. We can't say whether or not it makes sense statistically.

Creating Custom Rules Sets Based on a Template

Add your own custom rule to the rule set using another version of the **AddControlRuleRecord** method. This one specifies a template, N out of M values, a sigma level to attach the control rule to, and a flag on whether or not to display a limit line for the control rule. If you have multiple control rules attached to a given sigma level, you should only display a control line for one of them.

SPCChartObjects.AddControlRule Method

Visual Basic (Declaration)

```
Public Function AddControlRule ( _
        template As Integer, _
        n As Integer, _
        m As Integer, _
        sigmavalue As Double, _
        displaylimitline As Boolean _
) As Integer
```

C#

```
public int AddControlRule(
```

```
        int template,
        int n,
        int m,
        double sigmavalue,
        bool displaylimitline
)
```

Parameters

template

Type: System..::.Int32
Specifies the standardized template number.

n

Type: System..::.Int32
The n value for the n of m condition ///

m

Type: System..::.Int32
The m value for the n of m condition ///

sigmavalue

Type: System..::.Double
The sigma value associated with the limit ///

displaylimitline

Type: System..::.Boolean
True to display a limit line for the control limit ///

In your code it would something like:

[C#]

```
int template = 2; // N of M  Greater than limit value
int N = 10;
int M = 13;
double sigmavalue = 2; // control limit value is the +2-sigma value
bool displaylimitline = false; // no limit line.
this.PrimaryChart.AddControlRule(template, N, M,
    sigmavalue, displaylimitline);
```

[VB]

```
Dim template As Integer = 2
 ' N of M  Greater than limit value
 Dim N As Integer = 10
 Dim M As Integer = 13
```

```
Dim sigmavalue As Double = 2
' trending is not attached to a sigma value
Dim displaylimitline As Boolean = False
' no limit line.
Me.PrimaryChart.AddControlRule(template, N, M, sigmavalue, displaylimitline)
```

Creating Custom Rules Not Associated With Sigma Levels

Most of the preceding control rules are based on the mean and sigma of the current control chart. The trending rules (N of M increasing/ decreasing) are an exception, because they don't use the mean or sigma value anywhere in their evaluation. Regardless, since many of the named rules include trending rules, they are included with the previous section. There are a couple of other control rules not directly related to the mean and sigma value of the chart. The first is a simple numeric limit. The limit is meant to be independent of the mean and sigma level of the chart. It can also be considered a specification limit. We have three routines you can use to add a numeric control limit to a chart. The first, **AddSpecLimit**, creates a specification limit which monitors the main variable of the chart, and compares its value to the specified numeric threshold. It will display in the chart as a line with a limit string to the right of the plot area.

SPCChartObjects.AddSpecLimit Method

Visual Basic (Declaration)

```
Public Function AddSpecLimit ( _
        speclimittype As Integer, _
        value As Double, _
        displaystring As String, _
        attrib As ChartAttribute _
) As SPCControlPlotObjectData
```

C#

```
public SPCControlPlotObjectData AddSpecLimit(
        int speclimittype,
        double value,
        string displaystring,
        ChartAttribute attrib
)
```

Parameters

speclimittype

Type: System..::.Int32
Specifiy either SPCChartObjects.SPC_LOWER_SPEC_LIMIT or SPCChartObjects.SPC_UPPER_SPEC_LIMIT

value

Type: System..::.Double
Specifies the value of the specification limit.

displaystring
Type: System..::.String
The optional display string displayed to the right of the spec limit line.

attrib
Type: com.quinncurtis.chart2dnet..::.ChartAttribute
The line attributes of the spec limit line.

Return Value
The SPCControlPlotObjectData object of the specification limit.

[C#]

```
this.PrimaryChart.AddSpecLimit(SPCChartObjects.SPC_LOWER_SPEC_LIMIT,
    18.3, "L SPEC", new ChartAttribute(Color.Green, 3.0));
this.PrimaryChart.AddSpecLimit(SPCChartObjects.SPC_UPPER_SPEC_LIMIT,
    39.1, "H SPEC", new ChartAttribute(Color.Yellow, 3.0));
```

[VB]

```
Me.PrimaryChart.AddSpecLimit(SPCChartObjects.SPC_LOWER_SPEC_LIMIT,
    18.3, "L SPEC", new ChartAttribute(Color.Green, 3.0))
Me.PrimaryChart.AddSpecLimit(SPCChartObjects.SPC_UPPER_SPEC_LIMIT,
    39.1, "H SPEC", new ChartAttribute(Color.Yellow, 3.0))
```

The second, **AddNumericControlLimit**, creates a limit which monitors the value of one of the charts SPCCalculatedValueRecord object values. This is what you would use if you wanted to monitor a subgroup mean, range, sigma against some arbitrary control limit, since in the appropriate charts, the subgroup mean, range and sigma are SPCCalculatedValueRecord objects.

The type, and ordering of the SPCCalculatedValueRecord records is unique to each chart type. Below is a list of the chart types and the calculated values for each.

MEAN_RANGE_CHART
0. SPCCalculatedValueRecord.SPC_MEAN_CALC,
1. SPCCalculatedValueRecord.SPC_RANGE_CALC
2. SPCCalculatedValueRecord.SPC_SUM_CALC

MEDIAN_RANGE_CHART
0. SPCCalculatedValueRecord.SPC_MEDIAN_CALC
1. SPCCalculatedValueRecord.SPC_RANGE_CALC;

MEAN_SIGMA_CHART
0. SPCCalculatedValueRecord.SPC_MEAN_CALC
1. SPCCalculatedValueRecord.SPC_STD_DEVIATION_CALC
2. SPCCalculatedValueRecord.SPC_SUM_CALC

MEAN_SIGMA_CHART_VSS
0. SPCCalculatedValueRecord.SPC_MEAN_VSS_CALC
1. SPCCalculatedValueRecord.SPC_STD_DEVIATION_VSS_CALC

2. SPCCalculatedValueRecord.SPC_SUM_CALC
MEAN_VARIANCE_CHART
0. SPCCalculatedValueRecord.SPC_MEAN_CALC
1. SPCCalculatedValueRecord.SPC_VARIANCE_CALC
2. SPCCalculatedValueRecord.SPC_SUM_CALC
INDIVIDUAL_RANGE_CHART
0. SPCCalculatedValueRecord.SPC_INDIVIDUAL_COPY_VALUE
1. SPCCalculatedValueRecord.SPC_INDIVIDUAL_ABS_RANGE_CAL
MAMR_CHART
0. SPCCalculatedValueRecord.SPC_MA_CALC
1. SPCCalculatedValueRecord.SPC_MR_CALC
MAMS_CHART
0. SPCCalculatedValueRecord.SPC_MA_CALC
1. SPCCalculatedValueRecord.SPC_MS_CALC
EWMA_CHART
0. SPCCalculatedValueRecord.SPC_EWMA_CALC
1. SPCCalculatedValueRecord.SPC_MEAN_CALC
MA_CHART
0. SPCCalculatedValueRecord.SPC_MA_CALC
TABCUSUM_CHAR
0. SPCCalculatedValueRecord.SPC_CUSUM_CPLUS_CALC
1. SPCCalculatedValueRecord.SPC_CUSUM_CMINUS_CALC
2. SPCCalculatedValueRecord.SPC_MEAN_CALC, "MEAN"

PERCENT_DEFECTIVE_PARTS_CHART)
0. SPCCalculatedValueRecord.SPC_PERCENT_DEFECTIVE_PARTS_CALC
FRACTION_DEFECTIVE_PARTS_CHART
0. SPCCalculatedValueRecord.SPC_FRACTION_DEFECTIVE_PARTS_CALC
FRACTION_DEFECTIVE_PARTS_CHART_VSS
0. SPCCalculatedValueRecord.SPC_FRACTION_DEFECTIVE_PARTS_VSS_CALC
NUMBER_DEFECTIVE_PARTS_CHART
0. SPCCalculatedValueRecord.SPC_TOTAL_DEFECTIVE_PARTS_CALC
NUMBER_DEFECTS_CHART
0. SPCCalculatedValueRecord.SPC_TOTAL_DEFECTS_CALC
NUMBER_DEFECTS_PERUNIT_CHART
0. SPCCalculatedValueRecord.SPC_FRACTION_DEFECTS_CALC
NUMBER_DEFECTS_PERUNIT_CHART_VSS
0. SPCCalculatedValueRecord.SPC_FRACTION_DEFECTS_VSS_CALC
PERCENT_DEFECTIVE_PARTS_CHART_VSS
0. SPCCalculatedValueRecord.SPC_PERCENT_DEFECTIVE_PARTS_VSS_CALC
NUMBER_DEFECTS_PER_MILLION_CHART
0. SPCCalculatedValueRecord.SPC_TOTAL_DEFECTS_CALC
1. SPCCalculatedValueRecord.SPC_NUMBER_DEFECTS_PER_MILLION_CALC

SPCChartObjects.AddNumericControlLimit Method

Visual Basic (Declaration)

```
Public Function AddNumericControlLimit ( _
        sourcevar As SPCCalculatedValueRecord, _
        limtype As Integer, _
        value As Double, _
        displaystring As String, _
        addline As Boolean, _
        attrib As ChartAttribute _
) As SPCControlPlotObjectData
```

C#

```
public SPCControlPlotObjectData AddNumericControlLimit(
        SPCCalculatedValueRecord sourcevar,
        int limtype,
        double value,
        string displaystring,
        bool addline,
        ChartAttribute attrib
)
```

Parameters

sourcevar

Type: com.quinncurtis.spcchartspcchartnet..::.SPCCalculatedValueRecord
The SPCCalculatedValue source of the item to test.

limtype

Type: System..::.Int32
Specifiy either SPCChartObjects.SPC_LOWERTHAN_LIMIT or SPCChartObjects.SPC_GREATERTHAN_LIMIT

value

Type: System..::.Double
Specifies the value of the control limit.

displaystring

Type: System..::.String
The optional display string displayed to the right of the limit line.

addline

Type: System..::.Boolean
True and the limit is displayed as a line in the chart.

attrib

Type: com.quinncurtis.chart2dnet..::.ChartAttribute
The line attributes of the spec limit line.

Return Value

The SPCControlPlotObjectData object of the numeric limit.

[C#]

```
// this.ChartData.GetCalculatedValueRecord(0) returns the calcuated value which calculates the
subgroup mean

SPCCalculatedValueRecord cvr = this.ChartData.GetCalculatedValueRecord(0);
this.PrimaryChart.AddNumericControlLimit(cvr, SPCChartObjects.SPC_LOWER_SPEC_LIMIT,
       22.3, "L CV(0)", true, new ChartAttribute(Color.Green, 3.0));
this.PrimaryChart.AddNumericControlLimit(cvr, SPCChartObjects.SPC_UPPER_SPEC_LIMIT,
       32.1, "H  CV(0)", true, new ChartAttribute(Color.Yellow, 3.0));
```

[VB]

```
' Me.ChartData.GetCalculatedValueRecord(0) returns the calcuated value which calculates the
subgroup mean
Dim cvr As SPCCalculatedValueRecord = Me.ChartData.GetCalculatedValueRecord(0)

Me.PrimaryChart.AddNumericControlLimit(cvr, SPCChartObjects.SPC_LOWER_SPEC_LIMIT,
    22.3, "L  CV(0)", True, New ChartAttribute(Color.Green, 3.0))

Me.PrimaryChart.AddNumericControlLimit(cvr, SPCChartObjects.SPC_UPPER_SPEC_LIMIT,
    32.1, "H  CV(0)", True, New ChartAttribute(Color.Yellow, 3.0))
```

The third, **AddProcessCapabilityLimit**, creates a limit which monitors the value of one of the charts SPCProcessCapabilityRecord object values.

SPCChartObjects.AddProcessCapabilityControlLimit Method

Visual Basic (Declaration)

```
Public Function AddProcessCapabilityControlLimit ( _
        pcindex As Integer, _
        limtype As Integer, _
        value As Double, _
        displaystring As String, _
        attrib As ChartAttribute _
) As SPCControlPlotObjectData
```

C#

```
public SPCControlPlotObjectData AddProcessCapabilityControlLimit(
        int pcindex,
        int limtype,
        double value,
        string displaystring,
        ChartAttribute attrib
)
```

Parameters

pcindex

Type: System..::.Int32
Specify the process capability limit index (based on the order the process capabilities were added to the chart, starting at 0.

limtype

Type: System..::.Int32
Specifiy either SPCChartObjects.SPC_LOWER_PC_LIMIT or SPCChartObjects.SPC_UPPER_PC_LIMIT

value

Type: System..::.Double
Specifies the value of the limit.

displaystring

Type: System..::.String
Text included with the alarm if it is triggered.

attrib

Type: com.quinncurtis.chart2dnet..::.ChartAttribute
The line attributes of the spec limit line.

Return Value

The SPCControlPlotObjectData object of the specification limit.

[C#]

```
// Attached  control limits to the first Process Capability added to the chart
this.PrimaryChart.AddProcessCapabilityControlLimit(0, SPCChartObjects.SPC_LOWER_PC_LIMIT,
    0.195, "L Cpk", new ChartAttribute(Color.Green, 3.0));
this.PrimaryChart.AddProcessCapabilityControlLimit(0, SPCChartObjects.SPC_UPPER_PC_LIMIT,
    0.25, "H Cpk", new ChartAttribute(Color.Yellow, 3.0));

// Attached  control limits to the second Process Capability added to the chart
this.PrimaryChart.AddProcessCapabilityControlLimit(1, SPCChartObjects.SPC_LOWER_PC_LIMIT,
    0.195, "L Cpm", new ChartAttribute(Color.Green, 3.0));
this.PrimaryChart.AddProcessCapabilityControlLimit(1, SPCChartObjects.SPC_UPPER_PC_LIMIT,
    0.25, "H Cpm", new ChartAttribute(Color.Yellow, 3.0));
```

[VB]

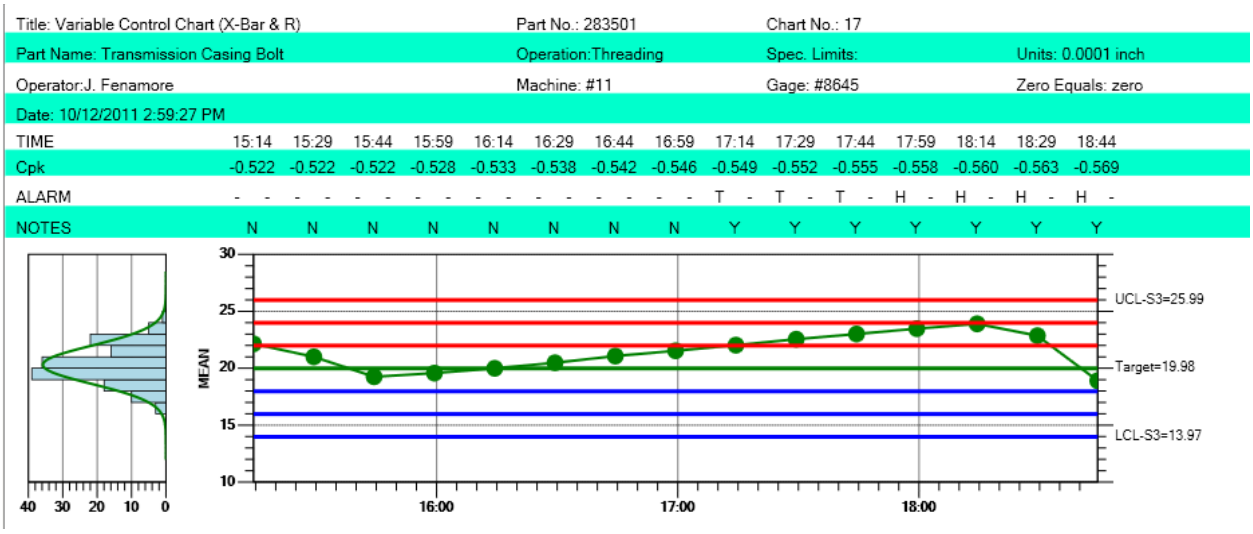
```
Me.PrimaryChart.AddProcessCapabilityControlLimit(0, SPCChartObjects.SPC_LOWER_PC_LIMIT,
    0.195, "L Cpk", New ChartAttribute(Color.Green, 3.0))
Me.PrimaryChart.AddProcessCapabilityControlLimit(0, SPCChartObjects.SPC_UPPER_PC_LIMIT,
    0.25, "H Cpk", New ChartAttribute(Color.Yellow, 3.0))

Me.PrimaryChart.AddProcessCapabilityControlLimit(1, SPCChartObjects.SPC_LOWER_PC_LIMIT,
    0.195, "L Cpm", New ChartAttribute(Color.Green, 3.0))
Me.PrimaryChart.AddProcessCapabilityControlLimit(1, SPCChartObjects.SPC_UPPER_PC_LIMIT,
    0.25, "H Cpm", New ChartAttribute(Color.Yellow, 3.0))
```

Enable Alarm Highlighting

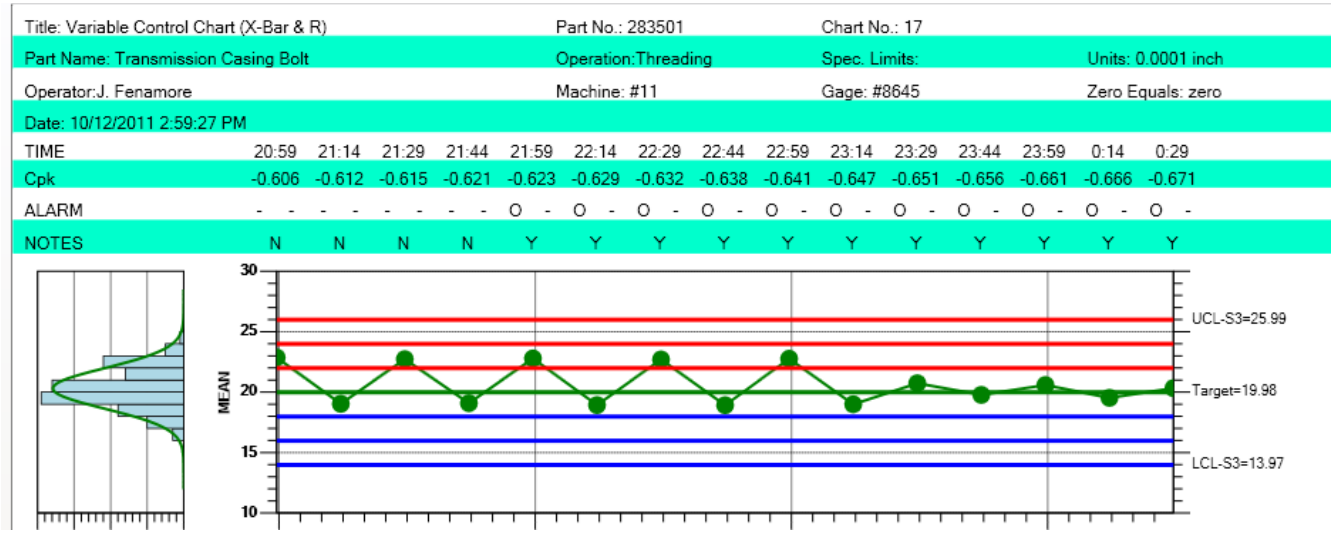
The alarm status line above is turned on/off using the **EnableAlarmStatusValues** property. We have set it on by default, so you will have to turn it off if you don't want it. Each sample interval has two small boxes that are labeled using one of several different characters, listed below. The most common are an "H" signifying a high alarm, a "L" signifying a low alarm, and a "-" signifying that there is no alarm. When specialized control rules are implemented, using the named rules, or custom rules involving trending, oscillation, or stratification, a "T", "O" or "S" may also appear.

"-"	No alarm condition
"H"	High - Measured value is above a high limit
"L"	Low - Measured value falls below a low limit
"T"	Trending - Measured value is trending up (or down).
"O"	Oscillation - Measured value is oscillating (alternating) up and down.
"S"	Stratification - Measured value is stuck in a narrow band.

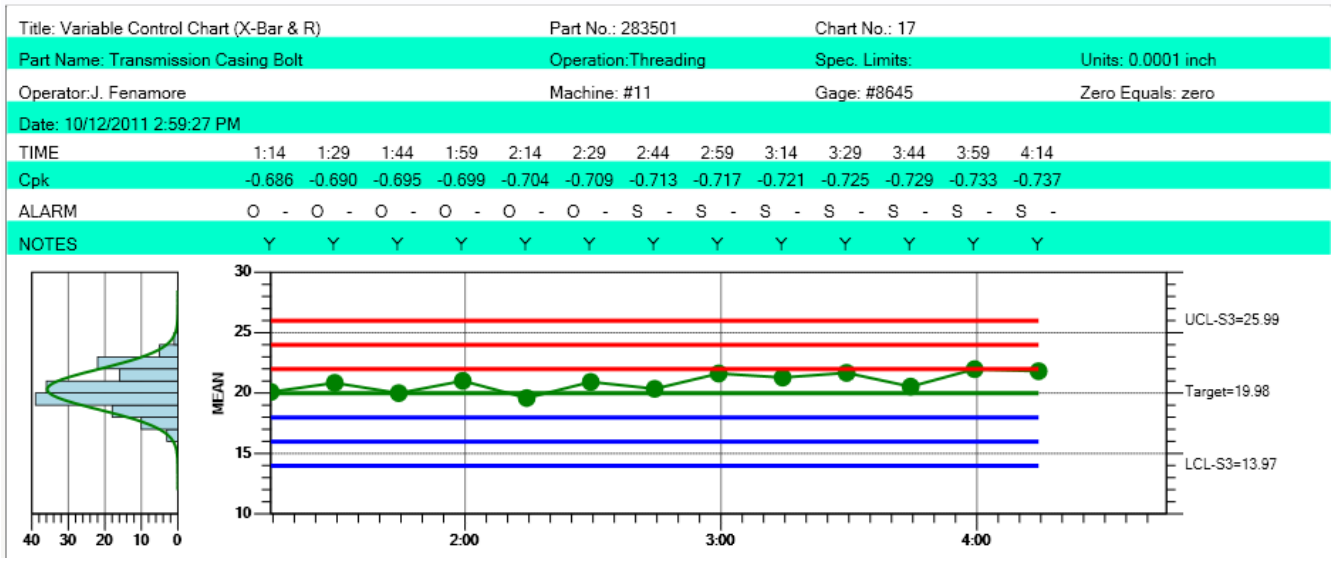
Trending


Title: Variable Control Chart (X-Bar & R)
Part No.: 283501
Chart No.: 17
Part Name: Transmission Casing Bolt
Operation:Threading
Spec. Limits:
Units: 0.0001 inch
Operator:J. Fenamore
Machine: #11
Gage: #8645
Zero Equals: zero
Date: 10/12/2011 2:59:27 PM
TIME 15:14 15:29 15:44 15:59 16:14 16:29 16:44 16:59 17:14 17:29 17:44 17:59 18:14 18:29 18:44
Cpk -0.522 -0.522 -0.522 -0.528 -0.533 -0.538 -0.542 -0.546 -0.549 -0.552 -0.555 -0.558 -0.560 -0.563 -0.569
ALARM - - - - - - - - - - - - T - T - T - H - H - H - H -
NOTES N N N N N N N N Y Y Y Y Y Y Y
MEAN
30
25
20
15
10
40 30 20 10 0
16:00
17:00
18:00
UCL-S3=25.99
Target=19.98
LCL-S3=13.97

Oscillation


Title: Variable Control Chart (X-Bar & R)
Part No.: 283501
Chart No.: 17
Part Name: Transmission Casing Bolt
Operation:Threading
Spec. Limits:
Units: 0.0001 inch
Operator:J. Fenamore
Machine: #11
Gage: #8645
Zero Equals: zero
Date: 10/12/2011 2:59:27 PM
TIME 20:59 21:14 21:29 21:44 21:59 22:14 22:29 22:44 22:59 23:14 23:29 23:44 23:59 0:14 0:29
Cpk -0.606 -0.612 -0.615 -0.621 -0.623 -0.629 -0.632 -0.638 -0.641 -0.647 -0.651 -0.656 -0.661 -0.666 -0.671
ALARM - - - - - - - O - O - O - O - O - O - O - O - O - O - O -
NOTES N N N N Y Y Y Y Y Y Y Y Y Y Y
MEAN
30
25
20
15
10
UCL-S3=25.99
Target=19.98
LCL-S3=13.97

Stratification


Title: Variable Control Chart (X-Bar & R)
Part No.: 283501
Chart No.: 17
Part Name: Transmission Casing Bolt
Operation:Threading
Spec. Limits:
Units: 0.0001 inch
Operator:J. Fenamore
Machine: #11
Gage: #8645
Zero Equals: zero
Date: 10/12/2011 2:59:27 PM
TIME 1:14 1:29 1:44 1:59 2:14 2:29 2:44 2:59 3:14 3:29 3:44 3:59 4:14
Cpk -0.686 -0.690 -0.695 -0.699 -0.704 -0.709 -0.713 -0.717 -0.721 -0.725 -0.729 -0.733 -0.737
ALARM O - O - O - O - O - O - S - S - S - S - S - S - S -
NOTES Y Y Y Y Y Y Y Y Y Y Y Y Y
MEAN
30
25
20
15
10
40 30 20 10 0
2:00
3:00
4:00
UCL-S3=25.99
Target=19.98
LCL-S3=13.97

[C#]

```
// Alarm status line
this.EnableAlarmStatusValues = false;
```

[VB]

```
'Alarm status line
Me.EnableAlarmStatusValues = False
```

Control Limit Alarm Event Handling

The **SPCControlChartData** class can throw an alarm event based on either the current alarm state, or an alarm transition from one alarm state to another. The **SPCControlLimitAlarmArgs** passes alarm data to the event handler. See *Chapter 5 - SPC Control Data and Alarm Classes,* for examples of using an alarm event handler.

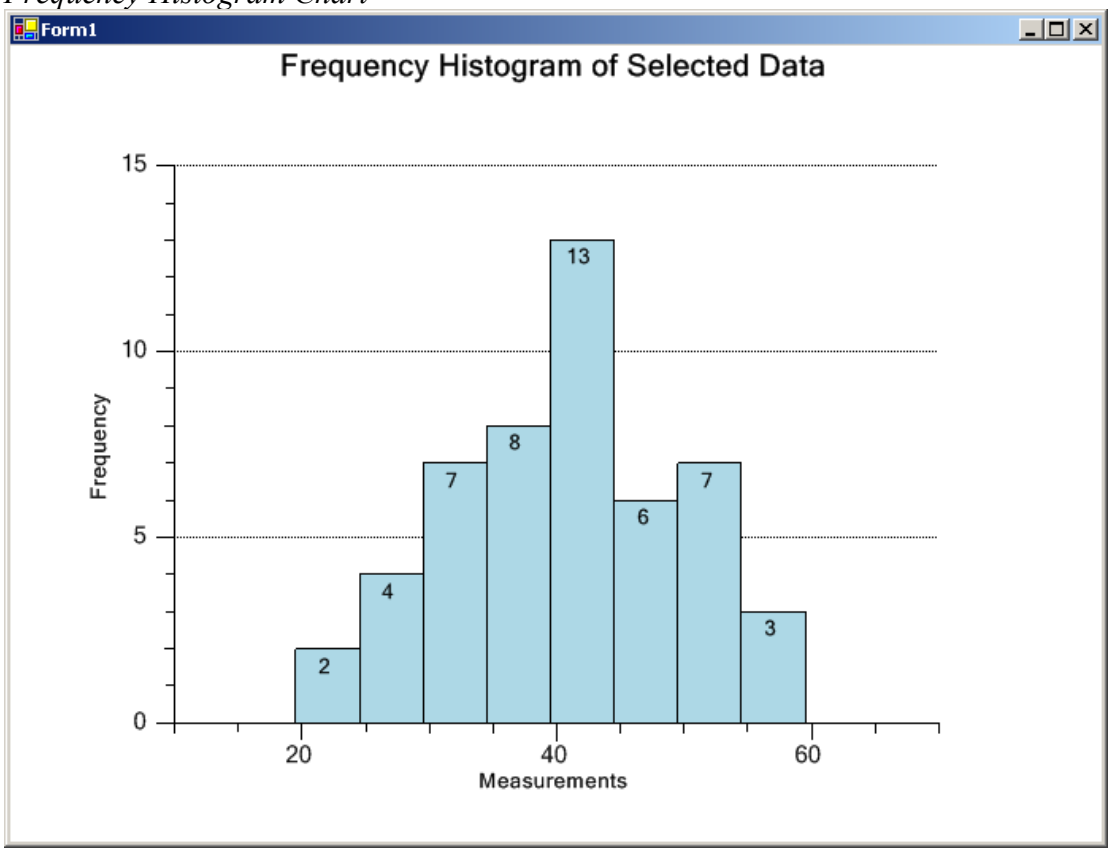
9. Frequency Histogram, Pareto Diagram and Normal-Probability Charts.

FrequencyHistogramChart
ParetoChart
ProbabilityChart

Frequency Histogram Chart

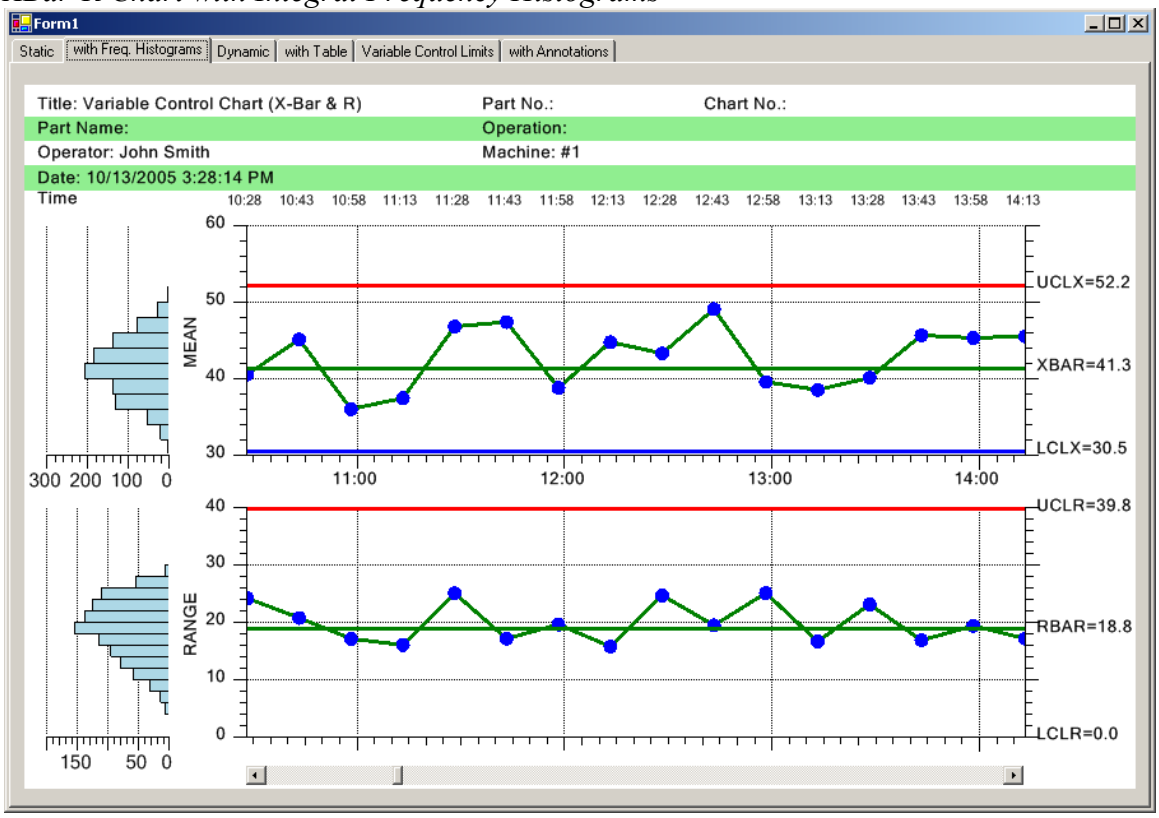
An SPC control chart will allow you to track the trend of critical variables in a production environment. It is important that the production engineer understand whether or not changes or variation in the critical variables are natural variations due to the tolerances inherent to the production machinery, or whether or not the variations are due to some systemic, assignable cause that needs to be addressed. If the changes in critical variables are due to the natural variations, then a frequency histogram of the variations will usually follow one of the common continuous (normal, exponential, gamma, Weibull) or discrete (binomial, Poisson, hypergeometric) distributions. It is the job of the SPC engineer to know what distribution best models his process. Periodically plotting of the variation of critical variables will give SPC engineer important information about the current state of the process. A typical frequency histogram looks like:

Frequency Histogram Chart



Viewing frequency histograms of both the variation in the primary variable (Mean, Median, count, or actual value), and the secondary variable (Range, Sigma or Moving Range) side-by-side with the SPC control chart makes it even easier to find out whether the variations are the result of natural variations or the result of some systemic change in the process.

XBar-R Chart with Integral Frequency Histograms



Creating an Independent (not part of a SPC chart) Frequency Histogram

The **FrequencyHistogramChart** class creates a standalone frequency histogram. It is a simple template where you need only supply data and set a few properties to create a proper frequency histogram. The example below extracted from the **FrequencyHistogram.FrequencyHistogramUserControl1** example program.

[C#]

```
public class FrequencyHistogramUserControl1:
    com.quinncurtis.spcchartnet.FrequencyHistogramChart
{
    public FrequencyHistogramUserControl1()
    {
        // This call is required by the Windows.Forms Form Designer.
        InitializeComponent();
        // Have the chart fill parent client area
        this.Dock = DockStyle.Fill;
        // Define and draw chart
        InitializeChart();
    }

    void InitializeChart()
    {
        // Frequency bins
```

```
    double [] freqLimits = {19.5, 24.5, 29.5, 34.5, 39.5, 44.5, 49.5, 54.5, 59.5};
        // data to be sorted into frequency bins
        double [] freqValues = {32,44,44,42,57,
                                26,51,23,33,27,
                                42,46,43,45,44,
                                53,37,25,38,44,
                                36,40,36,48,56,
                                47,40,58,45,38,
                                32,39,43,31,45,
                                41,37,31,39,33,
                                20,50,33,50,51,
                                28,51,40,52,43};
        // Initialize histogram
        this.InitFrequencyHistogram(freqLimits, freqValues);
        // Set bar orientation
        this.chartOrientation = ChartObj.VERT_DIR;
        // Build chart
        this.BuildChart();
    }
    .
    .
    .
}
```

[VB]

```
Public Class FrequencyHistogramUserControl1
    Inherits com.quinncurtis.spcchartnet.FrequencyHistogramChart


#Region " Windows Form Designer generated code "

    Public Sub New()
        MyBase.New()
        'This call is required by the Windows Form Designer.
        InitializeComponent()
        'Add any initialization after the InitializeComponent() call
        Me.Dock = DockStyle.Fill
        InitializeChart()
    End Sub
    .
    .
    .
#End Region



    Sub InitializeChart()
       ' Frequency bins
        Dim freqLimits() As Double = _
                {19.5, 24.5, 29.5, 34.5, 39.5, 44.5, 49.5, 54.5, 59.5}
        'data to be sorted into frequency bins
        Dim freqValues() As Double = _
                {32, 44, 44, 42, 57, 26, 51, 23, 33, _
                27, 42, 46, 43, 45, 44, 53, 37, 25, _
                38, 44, 36, 40, 36, 48, 56, 47, 40, _
                58, 45, 38, 32, 39, 43, 31, 45, 41, _
                37, 31, 39, 33, 20, 50, 33, 50, 51, _
                28, 51, 40, 52, 43}
        Me.InitFrequencyHistogram(freqLimits, freqValues) '
        Me.BuildChart()
    End Sub 'InitializeChart
End Class
```

All you have to do is supply the raw data, and the values of the frequency bins for which you want to accumulate values. The **FrequencyHistogramChart** class auto-scale a

coordinate system, creates the proper x- and y-axes, and draws the resulting frequency histogram as a bar plot.

FrequencyHistogramChart.InitFrequencyHistogram Method

Initializes the histogram frequency bin limits, and the data values for the histogram.

[VB]
```
Public Sub InitFrequencyHistogram( _
   ByVal frequencylimits As Double(), _
   ByVal frequencyvalues As Double() _
)
```
[C#]
```
public void InitFrequencyHistogram(
   double[] frequencylimits,
   double[] frequencyvalues
);
```

Parameters

frequencylimits

The frequency limits of the histogram bins.

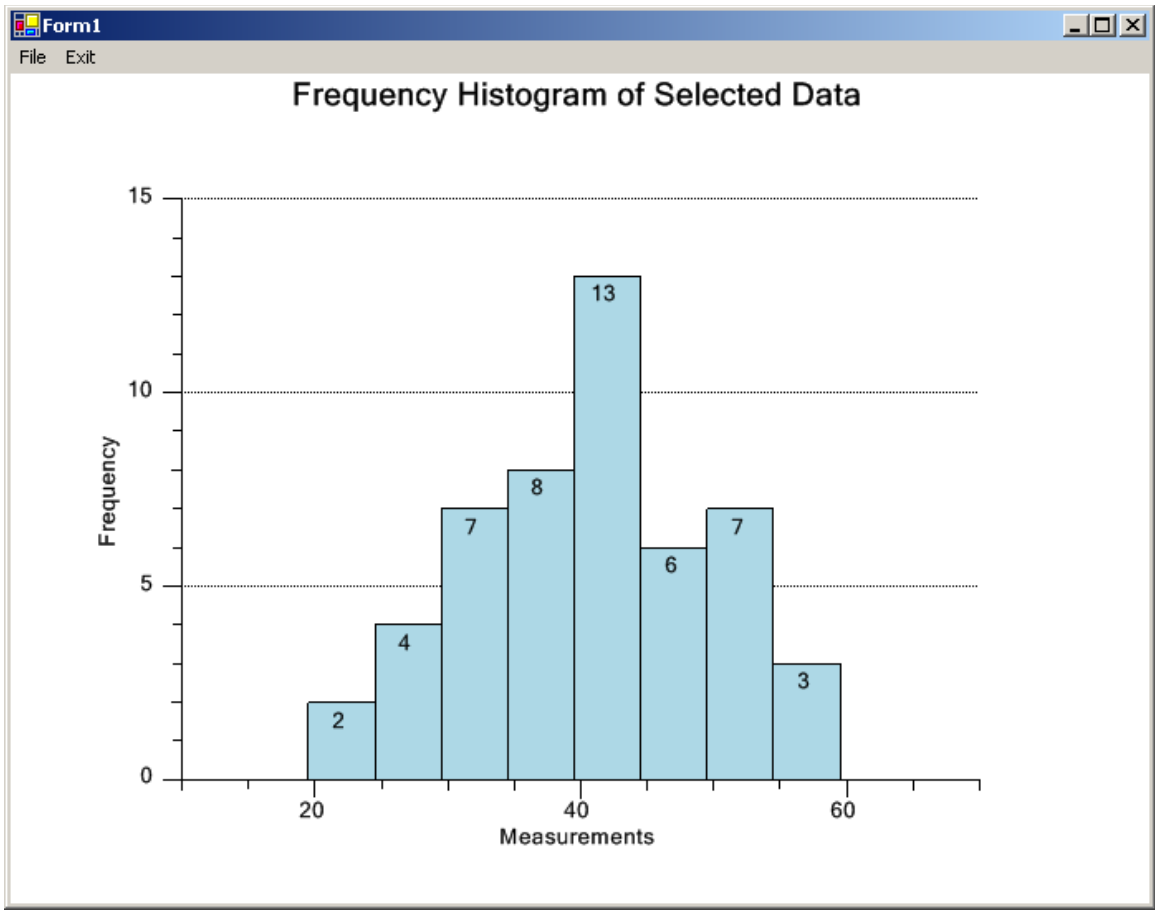
frequencyvalues

An array the values that are counted with respect to the frequency bins.

The image below uses the following data:

[C#]
```
// Frequency bins
double [] freqLimits = {100, 150, 200, 250, 300, 350, 400, 450, 500, 550, 600};
// data to be sorted into frequency bins
double [] freqValues =    {121, 349, 345, 322, 277,
                           162, 218, 134, 133, 476,
                           323, 367, 133, 354, 245,
                           434, 476, 352, 185, 144,
                           165, 105, 461, 386, 263,
                           476, 304, 180, 557, 482,
                           327, 293, 539, 318, 251,
                           218, 472, 218, 199, 330,
                           109, 101, 137, 300, 119,
                           380, 410, 206, 122, 238};
```

[VB]
```
' Frequency bins
 Dim freqLimits() As Double = _
    {100, 150, 200, 250, 300, 350, 400, 450, 500, 550, 600}  '
 ' data to be sorted into frequency bins
Dim freqValues() As Double = _
          {121, 349, 345, 322, 277, 162, 218, 134, 133, _
          476, 323, 367, 133, 354, 245, 434, 476, 352, _
          185, 144, 165, 105, 461, 386, 263, 476, 304, _
          180, 557, 482, 327, 293, 539, 318, 251, 218, _
          472, 218, 199, 330, 109, 101, 137, 300, 119, _
          380, 410, 206, 122, 238}
```



Once the Init routine is called, the chart can be further customized using the properties and methods below.

Public Static (Shared) Properties

DefaultAxisLabelsFont	Get/Set the default font used for the axes labels and axes titles.
DefaultChartFontString	Set/Get the default font used in the chart. This is a string specifying the name of the font.
DefaultDataValueFont	Get/Set the default font used for the numeric values labeling the bars.
DefaultFooterFont	Get/Set the font used for the chart footer.
DefaultMainTitleFont	Get/Set the font used for the main title.
DefaultSubHeadFont	Get/Set the font used for the main title.
DefaultToolTipFont	Set/Get the default font object used for the tooltip.

Public Instance Constructors

FrequencyHistogramChart	Overloaded. Initializes a new instance of the FrequencyHistogramChart class.

Public Instance Properties

AutoNormalCurve	Set to true and a normal curve with the same area as the histogram is plotted in the chart
BarAttrib	Get the primary bar attribute object for the bars of the histogram.
BarDataValue	Get the numeric label template object used to place numeric values on the bars.
BarFillColor	Sets the fill color for the chart object.
BarLineColor	Sets the line color for the chart object.
BarLineWidth	Sets the line width for the chart object.
ChartOrientation	Get/Set the orientation of the histogram bars in the chart.
CoordinateSystem	Get the coordinate system object for the histogram.
Datatooltip	Get the data tooltip object for the chart.
Footer	Get the footer object for the chart.
FrequencyHistogramPlot	Get the histogram plot object.
FrequencyLimits	Get the DoubleArray object that holds the limit values for the frequency bins of the histogram.
FrequencyValues	Get the DoubleArray object that holds the values that are counted with respect to the frequency bins.
GraphBackground	Get the graph background object.
GraphBorder	Get the default graph border for the chart.
HistogramDataset	Get the GroupDatset object that holds the data used to plot the histogram.
MainTitle	Get the main title object for the chart.
PlotBackground	Get the plot background object.
ResetOnDraw	Set/Get True the ChartView object list is cleared with each redraw
SubHead	Get the subhead title object for the chart.
XAxis	Get the x-axis object.
XAxisLab	Get the x-axis labels object.
XAxisTitle	Get the x-axis title object.
XGrid	Get the x-axis grid object.
YAxis	Get the y-axis object.
YAxisLab	Get the y-axis labels object. Accessible only

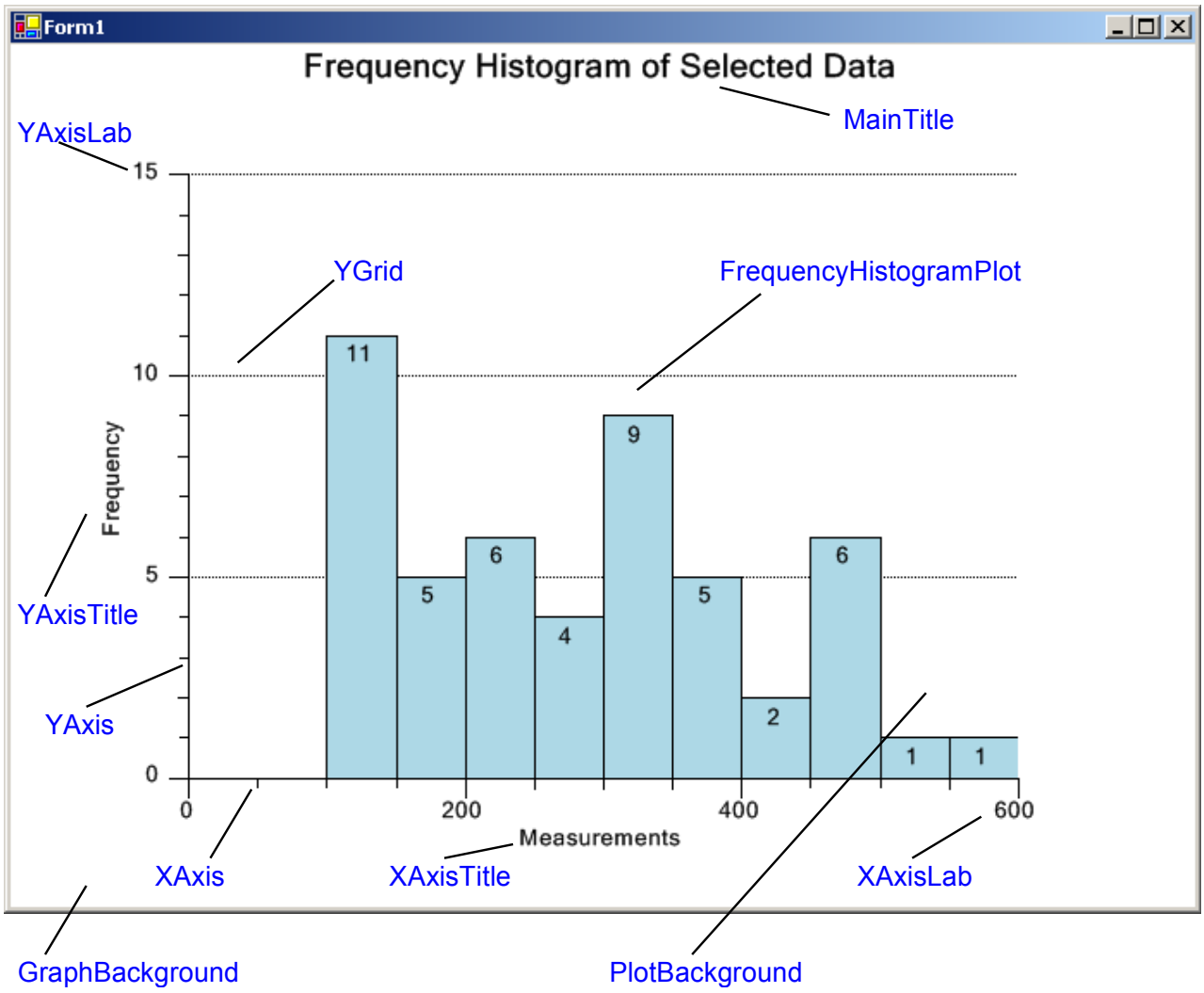
	after BuildGraph
YAxisTitle	Get the y-axis title object.
YGrid	Get the y-axis grid object.

Public Instance Methods

AddFrequencyHistogramControlLine	Add a control limit line to the frequency histogram
Copy	Overloaded. Copies the source FrequencyHistogramChart object.
InitFrequencyHistogram	Initializes the histogram frequency bin limits, and the data values to be analyzed for the histogram.
InitFrequencyHistogramDataset	Builds the histogram dataset, histogramDataset, using the values in frequencyValues and frequencyLimits.

Changing Default Characteristics of the Chart

A **FrequencyHistogramChart** object has one distinct graph with its own set of properties. Once the graph is initialized (using the **InitFrequencyHistogram**, or one of the **FrequencyHistogramChart** constructors**)**, you can modify the default characteristics of each graph using these properties. For example, you can change the color of y-axis, and the y-axis labels using the LineColor property of those objects.



[C#]

```
void InitializeChart()
{
    // Frequency bins
double [] freqLimits = {100, 150, 200, 250, 300, 350, 400, 450, 500, 550, 600};
  // data to be sorted into frequency bins
    double [] freqValues =    {121, 349, 345, 322, 277,
                               162, 218, 134, 133, 476,
                               323, 367, 133, 354, 245,
                               434, 476, 352, 185, 144,
                               165, 105, 461, 386, 263,
                               476, 304, 180, 557, 482,
                               327, 293, 539, 318, 251,
                               218, 472, 218, 199, 330,
                               109, 101, 137, 300, 119,
// Initialize histogram
    this.InitFrequencyHistogram(freqLimits, freqValues);
    this.YAxis.LineColor = Color.Green;
    this.YAxis.LineWidth = 3;
    this.YAxisLab.LineColor = Color.DarkMagenta;
    this.BuildChart();
}
```

[VB]

```
    Sub InitializeChart()
        ' Frequency bins
        Dim freqLimits() As Double = _
          {100, 150, 200, 250, 300, 350, 400, 450, 500, 550, 600}  '
        ' data to be sorted into frequency bins
        Dim freqValues() As Double = _
          {121, 349, 345, 322, 277, 162, 218, 134, 133, _
          476, 323, 367, 133, 354, 245, 434, 476, 352, _
          185, 144, 165, 105, 461, 386, 263, 476, 304, _
          180, 557, 482, 327, 293, 539, 318, 251, 218, _
          472, 218, 199, 330, 109, 101, 137, 300, 119, _
          380, 410, 206, 122, 238}

        Me.InitFrequencyHistogram(freqLimits, freqValues)

        Me.ChartOrientation = ChartObj.VERT_DIR
        Me.BarFillColor = Color.LightCoral
        Me.FrequencyHistogramPlot.SetSegmentFillColor(4, Color.Blue)

        Me.BuildChart()
    End Sub 'InitializeChart
```

Special Considerations

1. The **FrequencyHistogramChart** class uses the **QCChart2D HistogramPlot** plot object class to draw the histogram bars. That class uses individually assignable colors for each bar of the bar plot. The standard **ChartObj.LineColor** and **ChartObj.FillColor** properties do not work to change the color of the histogram bars in this case. Instead, you can change the histogram bar colors by calling **SetSegmentLineColor** and **SetSegmentFillColor**.

[C#]

```
For (int i=0; i < 9; i++}
{
  this.FrequencyHistogramPlot.SetSegmentFillColor(i,Color.Blue);
  this.FrequencyHistogramPlot.SetSegmentLineColor(i,Color.Black);
}
```

[VB]

```
Dim i As Integer
For i = 0 To 8
   Me.FrequencyHistogramPlot.SetSegmentFillColor(i, Color.Blue)
   Me.FrequencyHistogramPlot.SetSegmentLineColor(i, Color.Black)
Next i}
```

You can also use the utility properties, **BarFillColor**, **BarLineColor** and **BarLineWidth**, we added to the **FrequencyHistogramPlot** that will set all of the bars of the histogram plot at once.

[C#]

```
  this.BarFillColor = Color.Blue;
  this.BarLineColor = Color.Black;
```

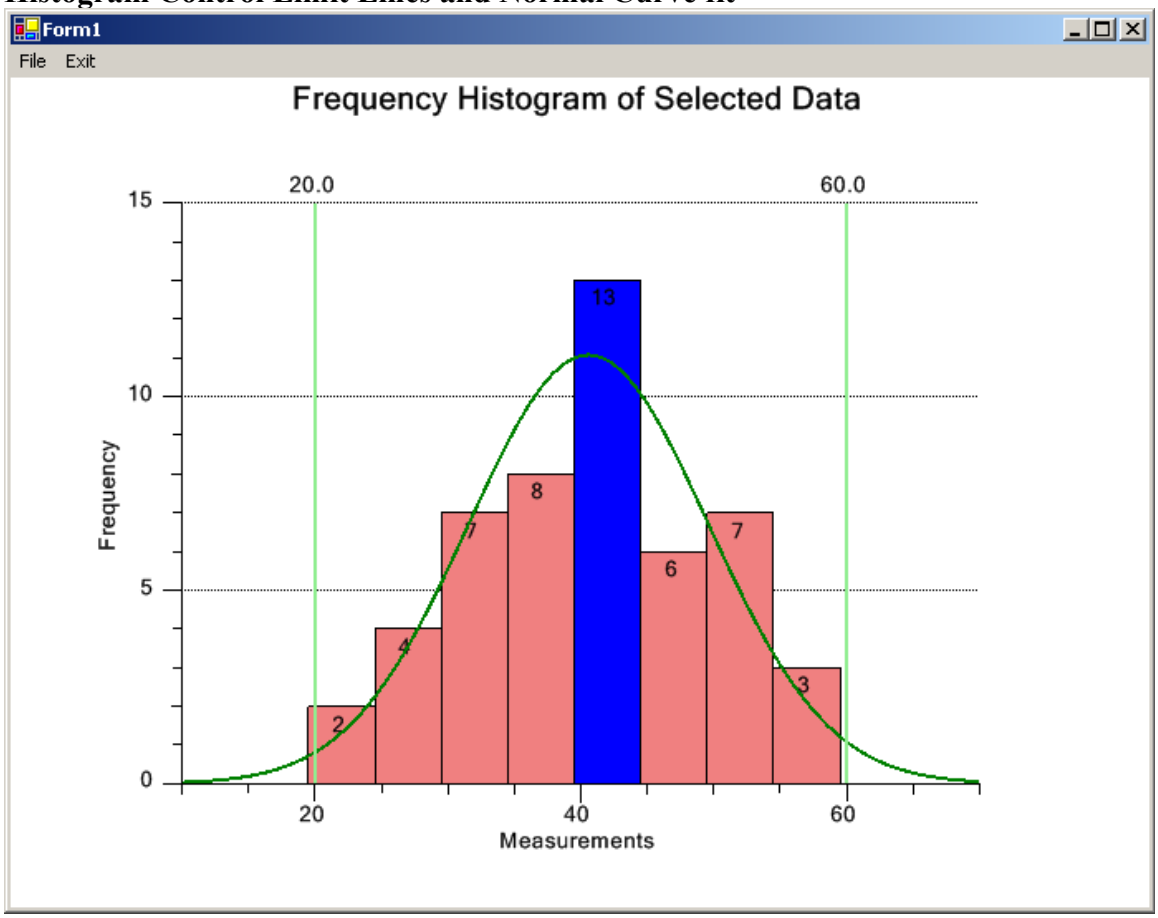
[VB]

```
Me.BarFillColor = Color.Blue
Me.BarLineColor = Color.Black
```

Adding Control Lines and Normal Curve to Histogram Plot

Revision 1.7 adds a couple of new features to the histogram plot. First, you can add control limit alarm lines to the histogram plot. The control limit lines will be parallel to the frequency axis. Second, a normal distribution curve can be overlaid on top of the histogram data. The parameters are selected to give the normal distribution curve the same mean, standard deviation and area as the underlying histogram data. If the underlying data is normal, then there should be a relatively close fit between the normal curve and the underlying frequency data.

Histogram Control Limit Lines and Normal Curve fit



[C#]

```
this.AddFrequencyHistogramControlLine(20.0,new ChartAttribute(Color.LightGreen,
2));
this.AddFrequencyHistogramControlLine(60.0,new ChartAttribute(Color.LightGreen,
2));
this.AutoNormalCurve = true;
```

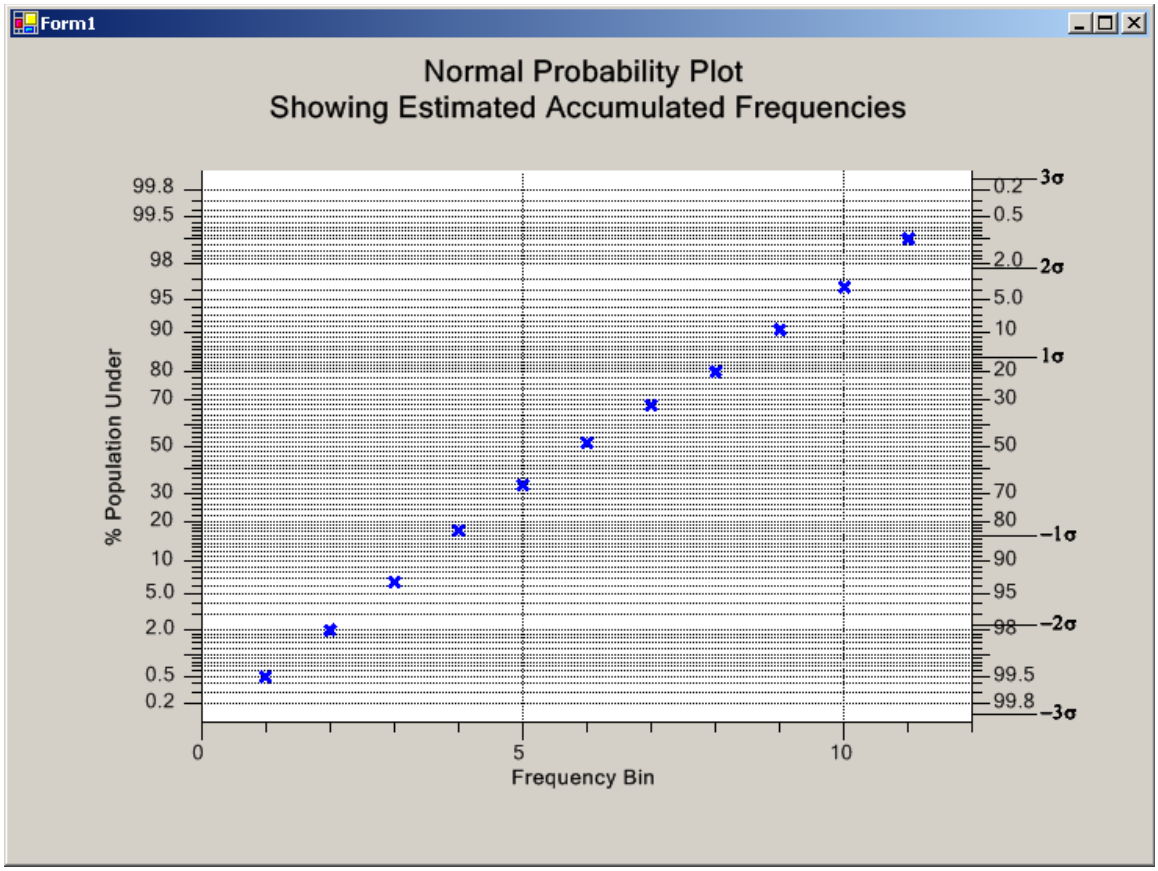
[VB]
```
Me.AddFrequencyHistogramControlLine(20.0, new ChartAttribute(Color.LightGreen, 2))
Me.AddFrequencyHistogramControlLine(60.0, new ChartAttribute(Color.LightGreen, 2))
Me.AutoNormalCurve = True
```

Probability Plots

Another important tool the SPC engineer uses to model the process variation is the probability plot. The probability plot is a simple way to test whether control chart measurements fit a normal distribution. Usually probability plot graphs are plotted by hand using special probability plot graph paper. We have added probability scale and axis classes that enable you to plot probability plots directly on the computer. Control chart measurements that follow a normal distribution curve will plot as a straight line when plotted in a normal probability plot.

Creating a Probability Plot

Cumulative Normal Probability Chart



The **ProbabilityChart** class creates a standalone probability plot. It is a simple template where you need only supply data and set a few properties to create a proper frequency histogram. The example below is extracted from the **ProbabilityPlot.ProbabilityPlotUserControl1** example program.

[C#]

```
public class ProbabilityPlotUserControl1:
    com.quinncurtis.spcchartnet.ProbabilityChart
{
    public ProbabilityPlotUserControl1()
    {
        // This call is required by the Windows.Forms Form Designer.
        InitializeComponent();
        // Have the chart fill parent client area
        this.Dock = DockStyle.Fill;
        // Define and draw chart
        InitializeChart();
    }


    void InitializeChart()
    {
        // TODO: Add any initialization after the InitForm call
        double []x1 = {1,2,3,4,5,6,7,8,9};
        double []y1 = {2, 6, 13, 26, 58, 82, 93, 97,100};
        this.InitProbabilityChart(x1, y1);
        this.BuildChart();
    }
    .
    .
    .
}
```

[VB]

```
Public Class ProbabilityPlotUserControl1
    Inherits com.quinncurtis.spcchartnet.ProbabilityChart

#Region " Windows Form Designer generated code "

    Public Sub New()
        MyBase.New()

        'This call is required by the Windows Form Designer.
        InitializeComponent()
        'Add any initialization after the InitializeComponent() call
         Me.Dock = DockStyle.Fill
        InitializeChart()
    End Sub
    .
    .
    .
#End Region

    Sub InitializeChart()
        ' TODO: Add any initialization after the InitForm call
        Dim x1() As Double = {1.0, 2, 3, 4, 5, 6, 7, 8, 9}
        Dim y1() As Double = {2, 6, 13, 26, 58, 82, 93, 97, 100}

        Me.InitProbabilityChart(x1, y1)
        Me.BuildChart() '
    End Sub 'InitializeChart '
    .
    .
```

```
    .
End Class
```

All you have to do is supply the raw data, and the values of the frequency bins for which you want to accumulate values. The **ProbabilityChart** class auto-scale a coordinate system, creates the proper x- and y-axes, and draws the resulting probability plot as a scatter plot.

ProbabilityChart.InitProbabilityChart Method

Initializes the x- and y-values of the data points plotted in the probability plot.

[VB]
```
Public Sub InitProbabilityChart( _
   ByVal xvalues As Double(), _
   ByVal yvalues As Double() _
)
```

[C#]
```
public void InitProbabilityChart(
   double[] xvalues,
   double[] yvalues
);
```

Parameters

xvalues

The x-values of the data points plotted in the probability plot.

yvalues

The y-values of the data points plotted in the probability plot.

Public Static (Shared) Properties

DefaultAxisLabelsFont	Set/Get default font object used for the axes labels.
DefaultAxisTitleFont	Set/Get the default font object used for the axes titles. Set this properties BuildGraph.
DefaultChartFontString	Set/Get the default font used in the chart. This is a string specifying the name of the font.
DefaultFooterFont	Set/Get the default font object used for the chart footer.
DefaultMainTitleFont	Set/Get the default font object used for the main chart title.
DefaultSigmaFont	Set/Get the default font object used for the axis labels sigma character.
DefaultSubHeadFont	Set/Get the default font object used for the subhead title.
DefaultToolTipFont	Set/Get the default font object used for the

	tooltip.

Public Instance Constructors

ProbabilityChart	Overloaded. Initializes a new instance of the ProbabilityChart class.

Public Instance Properties

CoordinateSystem	Get the probability coordinate system for the chart.
Datatooltip	Get the chart data tooltip.
DefaultGraphBorder	Get/Set the default graph border object for the chart.
Footer	Get the chart footer object.
GraphBackground	Get the graph background object.
MainTitle	Get the chart title object.
PlotAttrib	Get the default primary plot attribute object for the plot of the chart. Set attributes before BuildChart.
PlotBackground	Get the plot background object.
ProbabilityDataset	Get the dataset holding the data values of the plot.
ProbabilityPlot	Get probability plot scatter plot object.
ResetOnDraw	Set/Get True the ChartView object list is cleared with each redraw
SigmaAxis	Get the sigma y-axis object of the chart.
SigmaAxisLab	Get the sigma y-axis labels object of the chart.
SubHead	Get the chart subhead object.
SymbolSize	Get/Set the default symbol size. Set attributes before BuildChart.
TextTemplate	Get the default text object template for the data tooltip.
ToolTipSymbol	Get the tooltip symbol object for the data tooltip.
XAxis	Get the x-axis object of the chart.
XAxisLab	Get the x-axis labels object of the chart.
XAxisTitle	Get the x-axis title object of the of the chart.
XGrid	Get the x-axis grid object of the of the chart.
XValues	Get the DoubleArray of the x-values of the data points plotted in the probability plot.
XValueTemplate	Get the default x-value object template for the data tooltip.
YAxis1	Get the left probability y-axis object of the

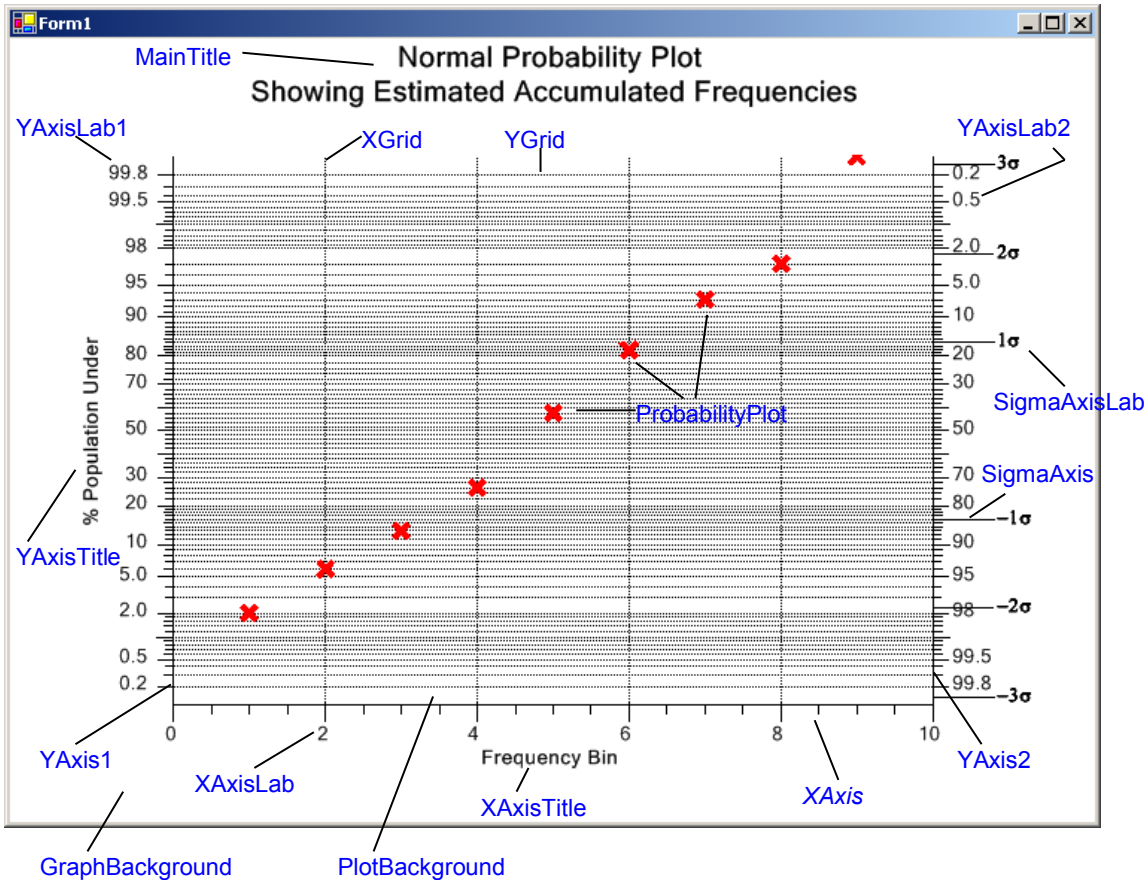
	chart.
YAxis2	Get the right probability y-axis object of the chart.
YAxisLab1	Get the left probability y-axis labels object of the chart.
YAxisLab2	Get the right probability y-axis labels object of the chart.
YAxisTitle	Get the y-axis title object of the of the chart.
YGrid	Get the y-axis title object of the of the chart.
YValues	Get the DoubleArray of the y-values of the data points plotted in the probability plot.
YValueTemplate	Get the default y-value object template for the data tooltip.

Public Instance Methods

BuildChart	Overloaded. Builds the probability chart using the base objects ChartView.
Copy	Overloaded. Copies the source ProbabilityChart object.
InitProbabilityChart	Initializes the x- and y-values of the data points plotted in the probability plot.
InitProbabilityDatasets	Builds the histogram dataset, histogramDataset, using the values in frequencyValues and frequencyLimits.

Changing Default Characteristics of the Chart

Once the graph is initialized (using the **InitProbabilityChart** , or one of the **ProbabilityChart** constructors**)**, you can modify the default characteristics of each graph using these properties. For example, you can change the color of y-axis, and the y-axis labels using the **LineColor** property of those objects.



[C#]

```
void InitializeChart()
{
    // TODO: Add any initialization after the InitForm call
    double []x1 = {1,2,3,4,5,6,7,8,9};
    double []y1 = {2, 6, 13, 26, 58, 82, 93, 97,100};
    this.InitProbabilityChart(x1, y1);

    this.ProbabilityPlot.LineColor = Color.Red;
    this.ProbabilityPlot.ChartObjAttributes.SymbolSize = 12;
    this.YAxis1.LineColor = Color.Green;
    this.YAxis1.LineWidth = 3;
    this.YAxis2.LineColor = Color.Blue;
    this.YAxis2.LineWidth = 3;
    this.YAxisLab1.LineColor = Color.DarkMagenta;
    this.BuildChart();
}
```

[VB]

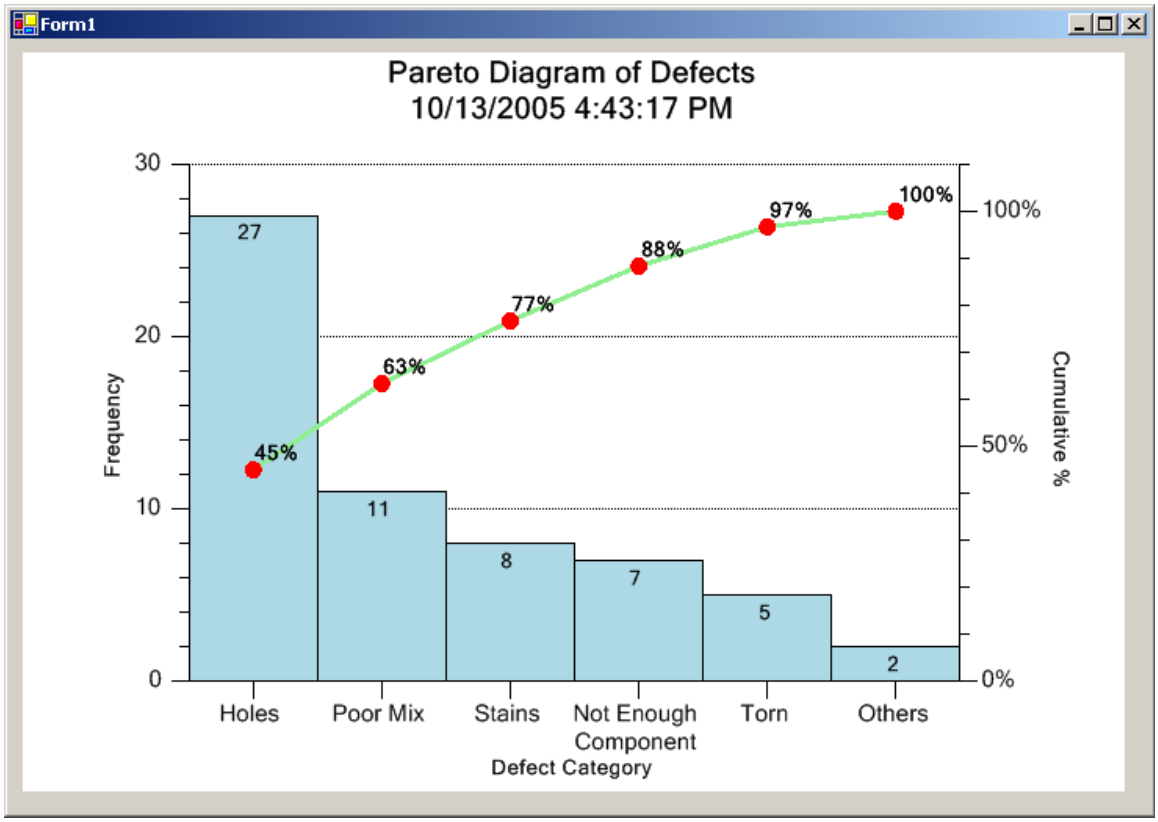
```
    Sub InitializeChart()
        ' TODO: Add any initialization after the InitForm call
        Dim x1() As Double = {1.0, 2, 3, 4, 5, 6, 7, 8, 9}
        Dim y1() As Double = {2, 6, 13, 26, 58, 82, 93, 97, 100}

        Me.InitProbabilityChart(x1, y1)

        Me.ProbabilityPlot.SetColor(Color.Red) '

        ' sets both line and fill color
        Me.ProbabilityPlot.ChartObjAttributes.SymbolSize = 12
```

```
        Me.YAxis1.LineColor = Color.Green
        Me.YAxis1.LineWidth = 3
        Me.ProbabilityPlot.LineColor = Color.Red
        Me.ProbabilityPlot.ChartObjAttributes.SymbolSize = 12

        Me.YAxis2.LineColor = Color.Blue
        Me.YAxis2.LineWidth = 3
        Me.YAxisLab1.LineColor = Color.DarkMagenta

        Me.BuildChart() '

    End Sub 'InitializeChart '
```

Pareto Diagrams

The Pareto diagram is special type of bar graph combined with a line plot, plotted in a chart that uses two different y-axis scales. The bar graph scale is a frequency scale that measures the number of times a specific problem has occurred. The line plot scale is a cumulative percentage scale.

Pareto Chart



The chart is easy to interpret. The tallest bar, the left-most one in a Pareto diagram, is the problem that has the most frequent occurrence. The shortest bar, the right-most one, is the problem that has the least frequent occurrence. Time spend on fixing the biggest problem will have the greatest affect on the overall problem rate. This is a simplistic view of actual Pareto analysis, which would usually take into account the cost effectiveness of

fixing a specific problem. Never less, it is powerful communication tool that the SPC engineer can use in trying to identify and solve production problems.

Creating a Pareto Diagram

The **ParetoChart** class creates a standalone Pareto Diagram chart. It is a simple template where you need only supply data and set a few properties to create a proper frequency histogram. The example below is from the ParetoPlotUserControl1 file of the ParetoDiagram example program.

[C#]

```
public class ParetoPlotUserControl1 : com.quinncurtis.spcchartnet.ParetoChart
{
        /// <summary>
        /// Required designer variable.
        /// </summary>
        private System.ComponentModel.Container components = null;

        public ParetoPlotUserControl1()
        {
            // This call is required by the Windows.Forms Form Designer.
            InitializeComponent();

            // Have the chart fill parent client area
            this.Dock = DockStyle.Fill;
            // Define and draw chart
            InitializeChart();
        }

        void InitializeChart()
        {
            // add Pareto chart categories, values and strings
            this.AddCategoryItem(5, "Torn");
            this.AddCategoryItem(7, "Not Enough\nComponent");
            this.AddCategoryItem(2, "Others");
            this.AddCategoryItem(11, "Poor Mix");
            this.AddCategoryItem(27, "Holes");
            this.AddCategoryItem(8, "Stains");
            // Build chart
            this.BuildChart();

        }
    .
    .
    .
}
```

[VB]

```
Public Class ParetoPlotUserControl1
    Inherits com.quinncurtis.spcchartnet.ParetoChart
#Region " Windows Form Designer generated code "

    Public Sub New()
        MyBase.New()
        'This call is required by the Windows Form Designer.
        InitializeComponent()
        'Add any initialization after the InitializeComponent() call
        'Add any initialization after the InitializeComponent() call
        Me.Dock = DockStyle.Fill
        InitializeChart()
    End Sub

    .
```

```
    .
    .
#End Region

    Sub InitializeChart()
        ' add Pareto chart categories, values and strings
        Me.AddCategoryItem(5, "Torn")
        Me.AddCategoryItem(7, "Not Enough" + ControlChars.Lf + "Component")
        Me.AddCategoryItem(2, "Others")
        Me.AddCategoryItem(11, "Poor Mix")
        Me.AddCategoryItem(27, "Holes")
        Me.AddCategoryItem(8, "Stains")
        ' Build chart
        Me.BuildChart()
    End Sub 'InitializeChart

End Class
```

All you have to do is supply the raw data, and the values of the frequency bins for which you want to accumulate values. The **ParetoChart** class auto-scale a coordinate system, creates the proper x- and y-axes, and draws the resulting probability plot as a scatter plot.

ParetoChart.InitParetoChart Method

Initializes the x- and y-values of the data points plotted in the probability plot.

[VB]
```
Public Sub InitParetoChart( _
   ByVal categoryitems As Double(), _
   ByVal stringitems As String() _
)
```

[C#]
```
public void InitParetoChart (
   double[] categoryitems,
   string[] stringitems
);
```

Parameters

categoryitems
: The values for each category in the Pareto chart.

stringitems
: The strings identifying each category in the Pareto chart.

You can add the category item values and string item strings one by one using the **AddCategoryItem** method.

ParetoChart.AddCategoryItem Method

Add an item to the categoryValues and categoryStrings arrays.

[VB]
```
Public Sub AddCategoryItem( _
   ByVal itemfreq As Double, _
   ByVal itemstring As String _
)
```

[C#]
```
public void AddCategoryItem(
   double itemfreq,
   string itemstring
);
```

Parameters

itemfreq

The count of how many times this category has occurred.

itemstring

The string identifying the category item.

Public Static (Shared) Properties

DefaultAxisLabelsFont	Set/Get default font object used for the axes labels and axes titles. Set attributes before BuildChart.
DefaultChartFontString	Set/Get the default font used in the chart. This is a string specifying the name of the font.
DefaultFooterFont	Set/Get the default footer font. Set attributes before BuildChart.
DefaultMainTitleFont	Get/Set the default chart title font. Set attributes before BuildChart.
DefaultSubHeadFont	Get/Set the default chart title font. Set attributes before BuildChart.
DefaultToolTipFont	Set/Get the default font object used for the tooltip.

Public Instance Constructors

ParetoChart	Overloaded. Initializes a new instance of the ParetoChart class.

Public Instance Properties

BarAttrib	Get the default primary bar attribute object for the bars of the chart. Set attributes before BuildChart.
BarDataValue	Get the default numeric label template used to label the values of bar plot of the frequency histogram part of the chart. Set

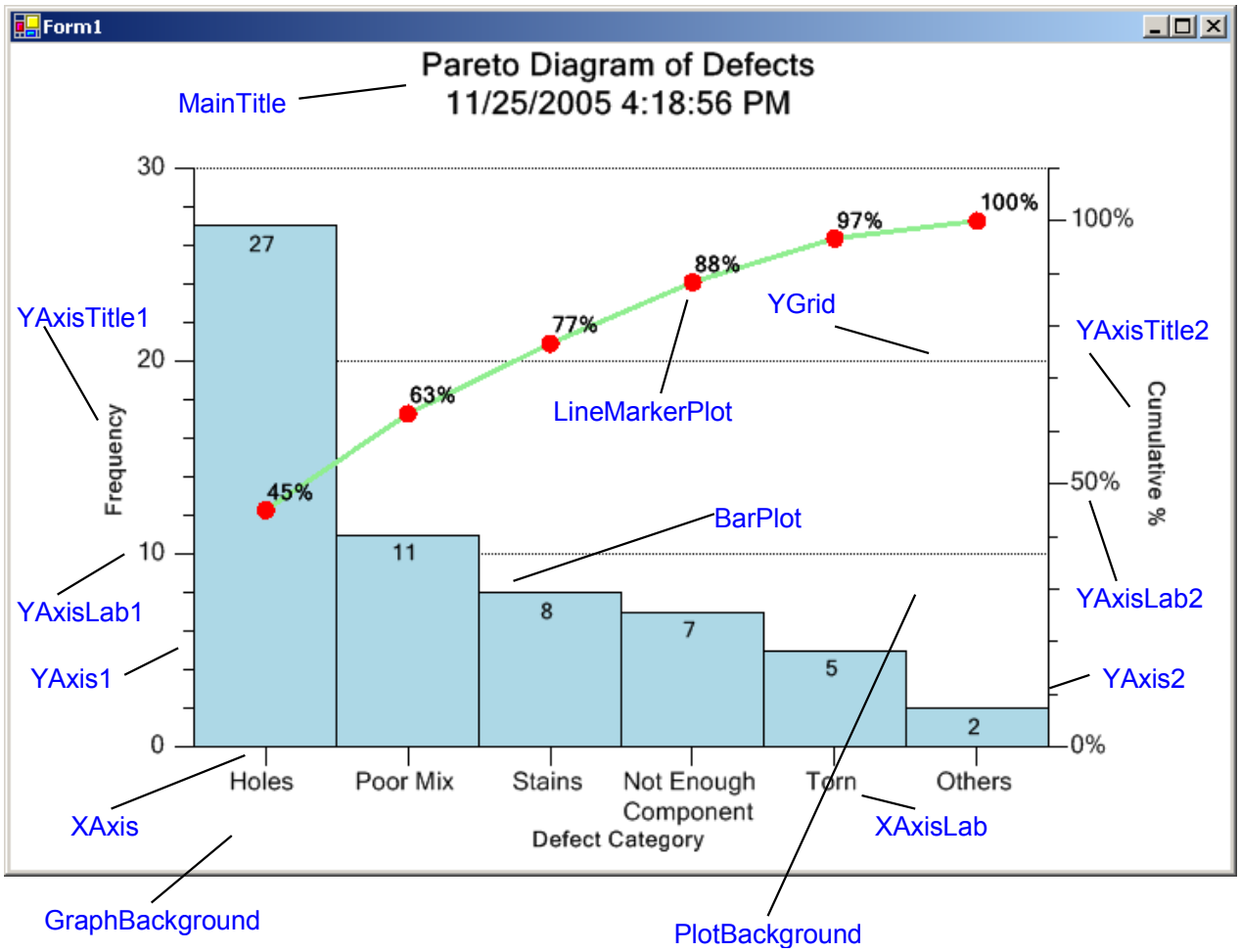
	attributes before BuildChart.
BarPlot	Get the histogram bar plot object of the frequency histogram part of the chart.
BarWidth	Get the default width value of the frequency histogram bars. Set attributes before BuildChart.
CategoryStrings	Get the StringArray object holding the strings used to label the categories of the Pareto plot. Set attributes before BuildChart.
CategoryValues	Get the DoubleArray object holding the category values used in building the Pareto plot. Set attributes before BuildChart.
CoordinateSystem1	Get the coordinate system object of the frequency histogram part of the chart.
CoordinateSystem2	Get the coordinate system object of the cumulative frequency part of the chart.
CumulativeFreqDataset	Get the dataset object used to hold the cumulative frequency values of the data plot.
Datatooltip	Get the data tooltip object for the chart.
DefaultGraphBorder	Get/Set the default graph border object for the chart. Set attributes before BuildChart.
Footer	Get the footer of the chart.
FrequencyDataset	Get the dataset object used to hold the frequency histogram values of the bar plot.
GraphBackground	Get the graph background object.
LineAttrib	Get the default primary line attribute object for the line plot of the chart. Set attributes before BuildChart.
LineMarkerPlot	Get the line marker plot object displaying the cumulative frequency part of the chart.
LineMarkerPlotDataValue	Get the default numeric template object used to label the line marker plot of the cumulative frequency part of the chart. Set attributes before BuildChart.
MainTitle	Get main title object of the chart.
PlotBackground	Get the plot background object.
ResetOnDraw	Set/Get True the ChartView object list is cleared with each redraw
Scale2StartY	Set/Get the starting y-value for the cumulative frequency scale.
Scale2StopY	Get/Set the ending y-value for the cumulative frequency scale.
SymbolAttrib	Get the default symbolAttrib attribute object

	for the symbols of the chart. Set attributes before BuildChart.
XAxis	Get the x-axis of the chart object.
XAxisLab	Get the x-axis string labels object of the chart.
XAxisTitle	Get the x-axis title object of the of the chart.
YAxis1	Get the y-axis object of the frequency histogram part of the chart.
YAxis2	Get the y-axis object of the cumulative frequency part of the chart.
YAxisLab1	Get the y-axis labels object of the frequency histogram part of the chart.
YAxisLab2	Get the y-axis numeric labels object of the cumulative frequency part of the chart.
YAxisTitle1	Get the y-axis title object of the frequency histogram part of the chart.
YAxisTitle2	Get the y-axis title object of the cumulative frequency part of the chart.
YGrid	Get the y-axis grid object of the chart.

Public Instance Methods

AddCategoryItem	Add an item to the categoryValues and categoryStrings arrays.
BuildChart	Overloaded. Builds the Pareto chart using the base objects ChartView.
Copy	Overloaded. Copies the source ParetoChart object.
InitParetoChart	Initializes the category values, and the category strings for the Pareto chart.
InitParetoChartsDatasets	Builds the histogram dataset, histogramDataset, using the values in frequencyValues and frequencyLimits.
SortCategoryItems	Sort the category values and category strings.

Changing Default Characteristics of the Chart



Once the graph is initialized (using the **InitParetoChart** , or one of the **ParetoChart** constructors**)**, you can modify the default characteristics of each graph using these properties. For example, you can change the color of y-axis, and the y-axis labels using the **LineColor** property of those objects.

[C#]

```
void InitializeChart()
{
    this.AddCategoryItem(5, "Torn");
    this.AddCategoryItem(7, "Not Enough\nComponent");
    this.AddCategoryItem(2, "Others");
    this.AddCategoryItem(11, "Poor Mix");
    this.AddCategoryItem(27, "Holes");
    this.AddCategoryItem(8, "Stains");
    this.LineMarkerPlot.LineAttributes.PrimaryColor = Color.Blue;
    this.LineMarkerPlot.SymbolAttributes.PrimaryColor = Color.Black;
    this.YAxis1.LineColor = Color.Green;
    this.YAxis1.LineWidth = 3;
    this.YAxis2.LineColor = Color.Blue;
    this.YAxis2.LineWidth = 3;
    this.YAxisLab1.LineColor = Color.DarkMagenta;

    this.BuildChart();
}
```

[VB]

```
Sub InitializeChart()
    ' add Pareto chart categories, values and strings
    Me.AddCategoryItem(5, "Torn")
    Me.AddCategoryItem(7, "Not Enough" + ControlChars.Lf + "Component")
    Me.AddCategoryItem(2, "Others")
    Me.AddCategoryItem(11, "Poor Mix")
    Me.AddCategoryItem(27, "Holes")
    Me.AddCategoryItem(8, "Stains")
    ' Build chart
    Me.LineMarkerPlot.LineAttributes.PrimaryColor = Color.Blue
    Me.LineMarkerPlot.SymbolAttributes.PrimaryColor = Color.Black
    Me.YAxis1.LineColor = Color.Green
    Me.YAxis1.LineWidth = 3
    Me.YAxis2.LineColor = Color.Blue
    Me.YAxis2.LineWidth = 3
    Me.YAxisLab1.LineColor = Color.DarkMagenta

    Me.BuildChart()
End Sub 'InitializeChart
```

10. File and Printer Rendering Classes

ChartPrint
BufferedImage

All of the chart classes described in this manual:

com.quinn-curtis.chart2dnet.ChartView
- FrequencyHistogramChart
- ParetoChart
- ProbabilityChart
- SPCChartBase
  - SPCBatchAttributeControlChart
  - SPCBatchVariableControlChart
  - SPCTimeAttributeControlChart
  - SPCTimeVariableControlChart

are derived from the **com.quinncurtis.chart2dnet.ChartView** class. The chart and table information displayed in these charts can be printed and saved to image files using the techniques described in the **QCChart2D** manual, QCChart2DNetManual.pdf. This chapter repeats that information, substituting examples extracted from the for **SPC Control Chart Tools for .Net** examples.

High quality B&W and color printing is an important feature of the charting library. The resulting graph renders on the printer using the resolution of the output device, for both text and graphical elements of the chart, and does not transfer a grainy image from the computer to the printer. The **QCChart2D for .***Net* software uses the Microsoft .Net **PrintDocument** component to implement printing. Since the aspect ratio of the printed page is different from the aspect ratio of common displays, options are included that allow different modes for positioning and sizing the chart on the printed page.

The **BufferedImage** class converts a chart into a .Net **Bitmap** object, or saves the chart to a file in any of the graphics formats supported by the **System.Drawing.Imaging.ImageFormat** class. The image file is placeable in a web page or an application program.

Printing a Chart

Class ChartPrint

ChartObj
|
+--ChartPrint

The **ChartPrint** class uses the Microsoft .Net **PrintDocument** component to implement printing. The class selects, setups, and outputs a chart to a printer.

ChartPrint constructor

```
[Visual Basic]
Overloads Public Sub New( _
   ByVal component As ChartView, _
   ByVal nsizemode As Integer _
)
[C#]
public ChartPrint(
   ChartView component,
   int nsizemode
);
```

component Specifies the **ChartView** object to be printed.

nsizemode Specifies the printer mapping mode. Use one of the mapping mode constants:

PRT_MAX	Print the view so that paper is used maximally. Text prints proportional to other objects, aspect ratio is NOT maintained
PRT_EXACT	Print the view at the same size as the screen, at least as far as .Net maintains a one to one correspondence in the printing engine. The aspect ration of the view is maintained.
PRT_RECT	Print the view to the specified rectangle, specified using the SetPrintRect method and normalized coordinates.

Call the **ChartPrint.DoPrintDialog** method after creating the **ChartPrint** object. Then call the **ChartPrint.DoPrintPage** method, rendering the chart to the printer. If the **DoPrintDialog** method is not called prior to **DoPrintPage**, the **DoPrintPage** method

automatically invokes the **DoPrintDialog** method. Subsequent calls to **DoPrintPage** will not invoke the **DoPrintDialog** method.

ChartPrint example **(extracted from the example program FrequencyHistogram.Form1)**

```
namespace FrequencyHistogram
{
    /// <summary>
    /// Summary description for Form1.
    /// </summary>
    public class Form1 : System.Windows.Forms.Form
    {
        private FrequencyHistogramUserControl1 frequencyHistogramUserControl1;
        .
        .
        .
        ChartPrint printobj = null;

        /// <summary>
        /// Required designer variable.
        /// </summary>
        private System.ComponentModel.Container components = null;

        public Form1()
        {
            //
            // Required for Windows Form Designer support
            //
            InitializeComponent();

            //
            // TODO: Add any constructor code after InitializeComponent call
            //
            // Create histogram user control
            frequencyHistogramUserControl1 = new FrequencyHistogramUserControl1();
            // Add control to form
            this.Controls.Add(frequencyHistogramUserControl1);
        }

        private void menuItem2_Click(object sender, System.EventArgs e)
        {
            if (frequencyHistogramUserControl1 != null)
                this.PageSetup(frequencyHistogramUserControl1, sender, e);
        }

        private void menuItem3_Click(object sender, System.EventArgs e)
        {
            if (frequencyHistogramUserControl1 != null)
                this.PrinterSetup(frequencyHistogramUserControl1, sender, e);

        }

        private void menuItem4_Click(object sender, System.EventArgs e)
        {
            if (frequencyHistogramUserControl1 != null)
                this.PrintPreview(frequencyHistogramUserControl1, sender, e);

        }

        private void menuItem5_Click(object sender, System.EventArgs e)
        {
            if (frequencyHistogramUserControl1 != null)
                this.PrintPage(frequencyHistogramUserControl1, sender, e);
        }


        private void menuItem8_Click(object sender, System.EventArgs e)
```

```
        {
            Application.Exit();
        }


        // This routine invokes the chart objects PageSetupItem method
    public void PageSetup(ChartView charview, object sender, System.EventArgs e)
        {
            if (charview != null)
            {
                if (printobj == null)
                {
                    printobj = new ChartPrint(charview);
                }
                else
                    printobj.PrintChartView = charview;
                printobj.PageSetupItem(sender, e);
            }
        }

        // This routine invokes the chart objects printer setup dialog method
public void PrinterSetup(ChartView charview, object sender, System.EventArgs e)
        {
            if (charview != null)
            {
                if (printobj == null)
                {
                    printobj = new ChartPrint(charview);
                }
                else
                    printobj.PrintChartView = charview;
                printobj.DoPrintDialog();
            }
        }

        // This routine invokes the chart objects PrintPreviewItem method
        public void PrintPreview(ChartView charview, object sender,
System.EventArgs e)
        {
            if (charview != null)
            {
                if (printobj == null)
                {
                    printobj = new ChartPrint(charview);
                }
                else
                    printobj.PrintChartView = charview;
                printobj.PrintPreviewItem(sender, e);
            }
        }

// This routine prints a chart by invoking the chart objects DocPrintPage method
    public void PrintPage(ChartView charview, object sender, System.EventArgs e)
        {
            if (charview != null)
            {
                if (printobj == null)
                {
                    printobj = new ChartPrint(charview);
                    printobj.DoPrintDialog();
                }
                else
                    printobj.PrintChartView = charview;

                printobj.DocPrintPage( sender,  e);
            }
        }
}
```

[Visual Basic]

```
Imports com.quinncurtis.chart2dnet
Imports com.quinncurtis.spcchartnet
Imports System.IO
Imports System.Text
Imports System.Drawing.Imaging

Public Class Form1
    Inherits System.Windows.Forms.Form

    Dim histogramplot As FrequencyHistogramUserControl1
    Dim printobj As ChartPrint

#Region " Windows Form Designer generated code "

    Public Sub New()
        MyBase.New()

        'This call is required by the Windows Form Designer.
        InitializeComponent()

        'Add any initialization after the InitializeComponent() call
        histogramplot = New FrequencyHistogramUserControl1()
        Me.Controls.Add(histogramplot)
    End Sub
    .
    .
    .

    Private Sub menuItem2_Click(ByVal sender As Object, _
        ByVal e As System.EventArgs) Handles MenuItem2.Click
        If Not (histogramplot Is Nothing) Then
            Me.PageSetup(histogramplot, sender, e)
        End If
    End Sub 'menuItem2_Click

    Private Sub menuItem3_Click(ByVal sender As Object, _
        ByVal e As System.EventArgs) Handles MenuItem3.Click
        If Not (histogramplot Is Nothing) Then
            Me.PrinterSetup(histogramplot, sender, e)
        End If
    End Sub 'menuItem3_Click

    Private Sub menuItem4_Click(ByVal sender As Object, _
        ByVal e As System.EventArgs) Handles MenuItem4.Click
        If Not (histogramplot Is Nothing) Then
            Me.PrintPreview(histogramplot, sender, e)
        End If
    End Sub 'menuItem4_Click

    Private Sub menuItem5_Click(ByVal sender As Object, _
        ByVal e As System.EventArgs) Handles MenuItem5.Click
        If Not (histogramplot Is Nothing) Then
            Me.PrintPage(histogramplot, sender, e)
        End If
    End Sub 'menuItem5_Click

    Private Sub menuItem8_Click(ByVal sender As Object, _
        ByVal e As System.EventArgs) Handles MenuItem8.Click
        Application.Exit()
    End Sub 'menuItem9_Click


    ' This routine invokes the chart objects PageSetupItem method
    Public Sub PageSetup(ByVal charview As ChartView, _
        ByVal sender As Object, ByVal e As System.EventArgs)
        If Not (charview Is Nothing) Then
            If printobj Is Nothing Then
                printobj = New ChartPrint(charview)
            Else
                printobj.PrintChartView = charview
```

```
            End If
            printobj.PageSetupItem(sender, e)
        End If
    End Sub 'PageSetup


    ' This routine invokes the chart objects printer setup dialog method
    Public Sub PrinterSetup(ByVal charview As ChartView, _
        ByVal sender As Object, ByVal e As System.EventArgs)
        If Not (charview Is Nothing) Then
            If printobj Is Nothing Then
                printobj = New ChartPrint(charview)
            Else
                printobj.PrintChartView = charview
            End If
            printobj.DoPrintDialog()
        End If
    End Sub 'PrinterSetup


    ' This routine invokes the chart objects PrintPreviewItem method
    Public Sub PrintPreview(ByVal charview As ChartView, _
        ByVal sender As Object, ByVal e As System.EventArgs)
        If Not (charview Is Nothing) Then
            If printobj Is Nothing Then
                printobj = New ChartPrint(charview)
            Else
                printobj.PrintChartView = charview
            End If
            printobj.PrintPreviewItem(sender, e)
        End If
    End Sub 'PrintPreview


    ' This routine prints a chart by invoking the chart objects DocPrintPage
method
    Public Sub PrintPage(ByVal charview As ChartView, _
        ByVal sender As Object, ByVal e As System.EventArgs)
        If Not (charview Is Nothing) Then
            If printobj Is Nothing Then
                printobj = New ChartPrint(charview)
                printobj.DoPrintDialog()
            Else
                printobj.PrintChartView = charview
            End If
            printobj.DocPrintPage(sender, e)
        End If
    End Sub 'PrintPage
End Class
```

The example TimeVariableControlCharts demonstrates how to one chart among many displayed in a Tab control.

Capturing the Chart as a Buffered Image

Class BufferedImage

ChartObj

|

+-- BufferedImage

The **BufferedImage** class creates a **Bitmap** object that renders a **ChartView** object into an image buffer. The rendering takes place when the **BufferedImage**.Render method or **BufferedImage.SaveImage** method is called.

BufferedImage constructor

```
[VB]
Overloads Public Sub New( _
   ByVal component As ChartView, _
   ByVal imgformat As ImageFormat _
)

[Visual Basic]
Overloads Public Sub New( _
   ByVal component As ChartView _
)

[C#]
public BufferedImage(
   ChartView component,
   ImageFormat imgformat
);


public BufferedImage(
   ChartView component
);
```

component	The **ChartView** object that is the source for the chart image.
imageformat	An image format object specifying the format of the rendered image.

The **BufferedImage.GetBufferedImage** method converts the chart to the .Net **Bitmap** object specified by the imageformat object and returns a reference the resulting bitmap.

BufferedImage example (extracted from the example program FrequencyHistogram.Form1)

[C#]

```
// This routine displays a dialog box, in response to an event, that prompts
// the user for the name and
// file type of the image to be saved.
//  The file type is derived from the file extension.
// The chart represented by "this" object is saved to the file
// using the specified format.
public void SaveAsFile(ChartView chartview, object sender, System.EventArgs e)
{
    String filename = this.Name;
    SaveFileDialog imagefilechooser = new SaveFileDialog();
    imagefilechooser.Filter =
"Image Files(*.BMP;*.JPG;*.GIF;*.TIFF;*.PNG)|*.BMP;*.JPG;*.GIF;*.TIFF;*.PNG|All
files (*.*)|*.*";
    imagefilechooser.FileName = filename;
```

```
    if (imagefilechooser.ShowDialog() == DialogResult.OK)
    {
        filename = imagefilechooser.FileName;
        FileInfo fileinformation = new FileInfo(filename);
        String fileext = fileinformation.Extension;
        fileext = fileext.ToUpper();
        ImageFormat fileimageformat;
        if (fileext == ".BMP" )
            fileimageformat = ImageFormat.Bmp;
        else if ((fileext == ".JPG") || (fileext == ".JPEG"))
            fileimageformat = ImageFormat.Jpeg;
        else if ((fileext == ".GIF"))
            fileimageformat = ImageFormat.Gif;
        else if ((fileext == ".TIF") || (fileext == ".TIFF"))
            fileimageformat = ImageFormat.Tiff;
        else if ((fileext == ".PNG"))
            fileimageformat = ImageFormat.Png;
        else
            fileimageformat = ImageFormat.Bmp;

        BufferedImage savegraph = new BufferedImage(chartview, fileimageformat);
        savegraph.Render();
        savegraph.SaveImage(filename);
    }
}
```

[VB]

```
' This routine displays a dialog box, in response to an event, that prompts
' the user for the name and
' file type of the image to be saved. The file type is derived from the file
'  extension.
' The chart represented by "this" object is saved to the file using the specified
' format.

Public Sub SaveAsFile(ByVal chartview As ChartView, _
    ByVal sender As Object, ByVal e As System.EventArgs)
    Dim filename As [String] = Me.Name
    Dim imagefilechooser As New SaveFileDialog()
    imagefilechooser.Filter = _
"Image Files(*.BMP;*.JPG;*.GIF;*.TIFF;*.PNG)|*.BMP;*.JPG;*.GIF;*.TIFF;*.PNG|All
files (*.*)|*.*"
     imagefilechooser.FileName = filename
     If imagefilechooser.ShowDialog() = DialogResult.OK Then
         filename = imagefilechooser.FileName
         Dim fileinformation As New FileInfo(filename)
         Dim fileext As [String] = fileinformation.Extension
         fileext = fileext.ToUpper()
         Dim fileimageformat As ImageFormat
         If fileext = ".BMP" Then
             fileimageformat = ImageFormat.Bmp
         Else
             If fileext = ".JPG" Or fileext = ".JPEG" Then
                 fileimageformat = ImageFormat.Jpeg
             Else
                 If fileext = ".GIF" Then
                     fileimageformat = ImageFormat.Gif
                 Else
                     If fileext = ".TIF" Or fileext = ".TIFF" Then
                         fileimageformat = ImageFormat.Tiff
                     Else
                         If fileext = ".PNG" Then
                             fileimageformat = ImageFormat.Png
                         Else
                            fileimageformat = ImageFormat.Bmp
                         End If
                     End If
                End If
```

```
            End If
        End If
        Dim savegraph As New BufferedImage(chartview, fileimageformat)
        savegraph.Render()
        savegraph.SaveImage(filename)
    End If
End Sub 'SaveAsFile
```

11. Regionalization for non-USA English Markets

SPCChartStrings

Starting with Revision 3.0, we provide a much improved structure for adjusting the software for different cultures and languages. All of the pre-defined strings in the software have been moved to the static class SPCChartStrings, which can be modified at run-time, or, if you have the QCSPCChartNet.dll source code, at compile time. You can create multiple sets of strings, one for each unique region you sell to, and initialize the software to that set at run-time. While something similar is often done using resource files in the final .Net application program, it was not possible to add a user-customizable resource file to a pre-compiled library, like our QCSPCChartNet dll.

Apart from the strings, there are a couple other areas which benefit from regionalization. First is the use of the "," (comma) in some locales as the decimal separator, in place of the "." (period). Our software uses the standard numeric conversion routines found in .Net, for converting numeric values to strings, and these automatically take into account the proper format for the region recognized by the computer. So, you shouldn't have to do anything there.

Also, date/time values are subject to regional differences; specifically the order of the month-day-year in short form strings of the form 10/1/2011 ("M/dd/yyyy" US English format), compared to 1/10/2011 (("dd/M/yyyy" European format). There a couple of date/time formats in the list below, located at the enumerated values **defaultDateFormat** and **defaultTimeStampFormat.** You should change those to whatever time format you want. The format specification is that used by the .Net DateTime.ToString method.

The **SPChartStrings** class looks like:

```
public static class SPCChartStrings
{
       public  enum   SPCStringEnum: int
        {
            empty=0,
            chartFont,
            highAlarmStatus,
            lowAlarmStatus,
            shortStringNo,
            shortStringYes,
            .
```

```
    .
    .

        };


        // US-en
        static String[] usEnglishStrings = {
            "",
            "Microsoft Sans Serif",
            "H",
            "L",
            "N",
            "Y",
               .
               .
               .

      };


        static ArrayList globalStringList = new ArrayList();

        public static String[] currentDefaultStrings = usEnglishStrings;
        .
        .
        .

}
```

The **SPCStringEnum** enumeration contains an item for every default string used in the software. Paired with that is the currentDefaultStringsList, which has one string element for every enumerated value in the **SPCStringEnum** enumeration. The software pulls the strings it uses from the currentDefaultStrings array. It is initialize by default with the usEnglishStrings array; the string values of which are listed in the tables below.

SPCStringEnum	Default Strings	Description
start=0	"start"	Marks the start of the enumeration
chartFont	"Microsoft Sans Serif"	default font string
highAlarmStatus	"H"	alarm status line - High short string
lowAlarmStatus	"L"	alarm status line - Low short string
shortStringNo	"N"	No short string
shortStringYes	"Y"	Yes short string
dataLogUserString	""	default data log user string

sPCControlChartDataTitle	"Variable Control Chart (X-Bar & R)"	Default chart title
zeroEqualsZero	"zero"	table zero string
timeValueRowHeader	"TIME"	TIME row header
alarmStatusValueRowHeader	"ALARM"	ALARM row header
numberSamplesValueRowHeader	"NO. INSP."	NO. INSP. row header
titleHeader	"Title: "	Title field caption
partNumberHeader	"Part No.: "	Part number field caption
chartNumberHeader	"Chart No.: "	Chart number field caption
partNameHeader	"Part Name: "	Part name field caption
operationHeader	"Operation:"	Operation field caption
operatorHeader	"Operator:"	Operator field caption
machineHeader	"Machine: "	Machine field caption
dateHeader	"Date: "	Date field caption
specificationLimitsHeader	"Spec. Limits: "	Spec limits field caption
gageHeader	"Gage: "	Chart number field caption
unitOfMeasureHeader	"Units: "	Chart number field caption
zeroEqualsHeader	"Zero Equals: "	Chart number field caption
defaultMean	"MEAN"	MEAN Calculated value row header
defaultMedian	"MEDIAN"	MEDIAN Calculated value row header
defaultRange	"RANGE"	RANGE Calculated value row header
defaultVariance	"VARIANCE"	VARIANCE Calculated value row header

defaultSigma	"SIGMA"	SIGMA Calculated value row header
defaultSum	"SUM"	SUM Calculated value row header
defaultSampleValue	"SAMPLE VALUE"	SAMPLE VALUE alculated value row header
defaultAbsRange	"ABS(RANGE)"	ABS(RANGE) Calculated value row header
defaultMovingAverage	""“MA”	
defaultCusumCPlus	""C+"	
defaultCusumCMinus	""C-"	
defaultEWMA	""EWMA"	
defaultPercentDefective	" "% DEF."	
defaultFractionDefective	""FRACT. DEF."	
defaultNumberDefective	""NO. DEF."	
defaultNumberDefects	""NO. DEF."	
defaultNumberDefectsPerUnit	""NO. DEF./UNIT"	
defaultNumberDefectsPerMillion	""DEF./MILLION"	
defaultPBar	""PBAR"	
defaultAttributeLCL	""LCLP"	
defaultAttributeUCL	""UCLP"	
defaultAbsMovingRange	"MR"	Moving Range Calculated value row header
defaultAbsMovingSigma	"MS"	Moving Sigam Calculated value row header
defaultX	"X"	Default string used to label centerline value of I-R chart.
defaultXBar	"XBAR"	Default string used to label centerline value for

		XBar chart
defaultRBar	"RBAR"	Default string used to label centerline value for Range chart
defaultTarget	"Target"	Default string used for target
defaultLowControlLimit	"LCL"	Default string used to label low control limit line
defaultLowAlarmMessage	"Low Alarm"	Default string used for low alarm limit message
defaultUpperControlLimit	"UCL"	Default string used to label high control limit line
defaultHighAlarmMessage	"High Alarm"	Default string used for high alarm limit message
defaultSampleRowHeaderPrefix	"Sample #"	Row header for Sample # rows
defaultDefectRowHeaderPrefix	"Defect #"	Row header for Defect # rows
batchColumnHead	"Batch #"	Default string used as the batch number column head in the log file.
timeStampColumn	"Time Stamp"	Default string used as the time stamp column head in the log file.
sampleValueColumn	"Sample #"	Default string used as the sample value column head in the log file.
notesColumn	"Notes"	Default string used as the notes value column head in the log file.
defaultDateFormat	"M/dd/yyyy"	Default date format used by the software.
defaultTimeStampFormat	"M/dd/yyyy HH:mm:ss"	Default full date/time format used by the software.
defaultDataLogFilenameRoot	"SPCDataLog"	Root string used for auto-naming of log data file.
dataLogFilename	"SPCDataLog"	Datalog default file name
frequencyHistogramXAxisTitle	"Measurements"	Frequency Histogram default x-axis title.
frequencyHistogramYAxisTitle	"Frequency"	Frequency Histogram default y-axis title.

frequencyHistogramMainTitle	"Frequency Histogram"	Frequency Histogram default main title.
paretoChartXAxisTitle	"Defect Category"	Pareto chart x-axis title
paretoChartYAxis1Title	"Frequency"	Pareto chart left y-axis title
paretoChartYAxis2Title	"Cumulative %"	Pareto chart right y-axis title
paretoChartMainTitle	"Pareto Diagram"	Pareto chart main title
probabilityChartXAxisTitle	"Frequency Bin"	Probability chart x-axis title
probabilityChartYAxisTitle	"% Population Under"	Probability chart y-axis title
probabilityChartMainTitle	"Normal Probability Plot"	Probability chart main title
basic	"Basic"	Basic rules string
weco	"WECO"	WECO rules string
wecowsupp	"WECO+SUPPLEMENTAL"	WECO and Supplemental Rules string
nelson	"Nelson"	Nelson rules string
aiag	"AIAG"	AIAG rules string
juran	"Juran"	Juran rules string
hughes	"Hughes"	Hughes rules string
gitlow	"Gitlow"	Gitlow rules string
duncan	"Duncan"	Duncan rules string
westgard	"Westgard"	Westgard rules string
primarychart	"Primary chart"	Used in alarm messages to specify the Primary Chart variable chart is in alarm
secondarychart	"Secondary chart"	Used in alarm messages to specify the Secondary

		Chart variable chart is in alarm
greaterthan	"greater than"	Used in alarm messages to specify that a greater than alarm limit has been violated
lessthan	"less than"	Used in alarm messages to specify that a less than alarm limit has been violated
above	"above"	Used in alarm messages to specify that values above a limit
below	"below"	Used in alarm messages to specify that values below a limit
increasing	"increasing"	Used in alarm messages to specify that values are increasing
decreasing	"decreasing"	Used in alarm messages to specify that values are decreasing
trending	"trending"	Used in alarm messages to specify that values are trending
within	"within"	Used in alarm messages to specify that values are within certain limits
outside	"outside"	Used in alarm messages to specify that values are outside certain limits
alternating	"alternating"	Used in alarm messages to specify that values are alternating about a limit value
centerline	"center line"	Used in alarm messages to specify the center line of the chart
r2s	"R2s"	Used in alarm messages to specify the R2s test
sigmaShort	"S"	alarm status line - sigma short string
beyondAlarmStatus	"B"	alarm status line - beyond short string
trendingAlarmStatus	"T"	alarm status line - trending short string
stratificationAlarmStatus	"S"	alarm status line - stratification short string
oscillationAlarmStatus	"O"	alarm status line - oscillation short string

r2sAlarmStatus	"R"	alarm status line - R2s short string
rule	"Rule"	used in alarm messages for word "Rule"
violation	"violation"	used in alarm messages for word "violation"
sigma	"sigma"	used in alarm messages for word "sigma"
target	"Target"	used in alarm messages for word "Target"
ucl	"UCL"	used in alarm messages for to designate Upper Control Limit
lcl	"LCL"	used in alarm messages for to designate Lower Control Limit
defaultCp	"Cp"	used to label Cp row of table
defaultCpl	"Cpl"	used to label Cpl row of table
defaultCpu	"Cpu"	used to label Cpu row of table
defaultCpk	"Cpk"	used to label Cpk row of table
defaultCpm	"Cpm"	used to label Cpm row of table
defaultPp	"PPp"	used to label Pp row of table
defaultPl	"Ppl"	used to label Pl row of table
defaultPu	"Ppu"	used to label Pu row of table
defaultPpk	"Ppk"	used to label Ppk row of table
end	"end"	Marks the end of the enumeration

The enumerated values can be used to access and modify any specific string.

```
String oldstring = SPCChartStrings.SetString(
     SPCChartStrings.SPCStringEnum.defaultMean,"AVERAGE");

oldstring = SPCChartStrings.SetString(
     SPCChartStrings.SPCStringEnum.defaultDateFormat,"dd/M/yyyy");
```

Where the static **SetString** method returns the previous value for the string.

The **SPCChartStrings** module is used to define default, and static strings, for the various **QCSPCChart** classes, when those classes are initialized. Trying to set the **SPCChartStrings** strings using **SetString** after any of the SPC charts have been instantiated will not have the desired effect. Since the SPC charts classes are normally instantiated in the main Window.xaml file, you must change any strings before that intialization takes place. The best way to do that is to initialize the string in a static method in the main Form file. You will find an example in the TimeVariableControlCharts.Form1.cs file. Call the static method using an initialization of a static variable in the global variables section of the class. This will guarantee that the strings get initialized first. Since the SPCChartStrings class is static, you can call it anytime. It does not need instantiation.

```
 public partial class Window1 : Window
    {
        DynamicXBarRChart dxbrc;
        .
        .
        .

        static bool initStringsComplete = InitStrings();

        public Window1()
        {


            InitializeComponent();

            InitializeCharts();
        }

        static bool InitStrings()
        {
           String oldstring =
SPCChartStrings.SetString(  SPCChartStrings.SPCStringEnum.defaultMean,"MEAN");
            // Euro standard
           // oldstring = SPCChartStrings.SetString(
           //      SPCChartStrings.SPCStringEnum.defaultDateFormat, "dd/M/yyyy");
            // us-Eng standard
            oldstring = SPCChartStrings.SetString(
```

```
                SPCChartStrings.SPCStringEnum.defaultDateFormat, "M/dd/yyyy");
            return true;
        }

.
.
}
```

You can change every string used in the software, line by line, using the technique above. Another way is to create a properly sized and initialized string array and change every string in the software with a single call to the **SPCChartStrings.SetCurrentDefaultStrings** method. You will find an example in the MiscBatchBasedControlCharts.Form1 example.

[C#]

```
static bool initStringsFlag = InitStrings();

static bool InitStrings()
{
        // US-en
   String[] usEnglishStrings = {
   "start", // used to mark the beginning of the array
   "Microsoft Sans Serif",  // default font string
   "H",           // alarm status line - High short string
   "L",           // alarm status line - Low short string
   "N",           // No short string
    "Y",           // Yes short string
    "",            // default data log user string
    "Variable Control Chart (X-Bar & R)", // Default chart title
    "zero",  // table zero string
    "TIME",  // TIME row header
    "ALARM",  // ALARM row header
    "NO. INSP.", // NO. INSP. row header
    "Title: ",   // Title field caption
    "Part No.: ", // Part number field caption
    "Chart No.: ", // Chart number field caption
   .
   .
   .

   "end"  // used to mark the end of the array
         };

        SPCChartStrings.SetCurrentDefaultStrings ( usEnglishStrings);
        return true;
       }
```

[VB]

```
  Shared initStringsFlag As Boolean = InitStrings()

  Private Shared Function InitStrings() As Boolean
    ' US-en

    Dim usEnglishStrings As [String]() = {"start", "Microsoft Sans Serif", "H", "L", "N", "Y", _
```

```
        "", "Variable Control Chart (X-Bar & R)", "zero", "TIME", "ALARM", "NO. INSP.", _
        "Title: ", "Part No.: ", "Chart No.: ", "Part Name: ", "Operation:", "Operator:", _
        "Machine: ", "Date: ", "Spec. Limits: ", "Gage: ", "Units: ", "Zero Equals: ", _
        "MEAN", "MEDIAN", "RANGE", "VARIANCE", "SIGMA", "SUM", _
        "SAMPLE VALUE", "ABS(RANGE)", "MA", "C+", "C-", "EWMA", _
        "% DEF.", "FRACT. DEF.", "NO. DEF.", "NO. DEF.", "NO. DEF./UNIT", "DEF./MILLION", _
        "PBAR", "LCLP", "UCLP", "MR", "MS", "X", _
        "XBAR", "RBAR", "Target", "LCL", "Low Alarm", "UCL", _
        "High Alarm", "Sample #", "Defect #", "Batch #", "Time Stamp", "Sample #", _
        "Notes", "M/dd/yyyy", "M/dd/yyyy HH:mm:ss", "SPCDataLog", "SPCDataLog", "Measurements", _
        "Frequency", "Frequency Histogram", "Defect Category", "Frequency", "Cumulative %", "Pareto
Diagram", _
        "Frequency Bin", "% Population Under", "Normal Probability Plot", "Basic", "WECO",
"WECO+SUPPLEMENTAL", _
        "Nelson", "AIAG", "Juran", "Hughes", "Gitlow", "Duncan", "Westgard", _
        "Primary chart", "Secondary chart", "greater than", "less than", "above", "below", _
        "increasing", "decreasing", "trending", "within", "outside", "alternating", _
        "center line", "R2s", "S", "B", "T", "S", "O", "R", _
        "Rule", "violation", "sigma", "Target", "UCL", "LCL", _
        "Cp", "Cpl", "Cpu", "Cpk", "Cpm", "Pp", _
        "Pl", "Pu", "Ppk", "end"}

    SPCChartStrings.SetCurrentDefaultStrings(usEnglishStrings)
    Return True
End Function
```

12. Using SPC Control Chart Tools for .Net to Create Windows Applications

(*** Critical Note ***) Running the Example Programs

The example programs for **SPC Control Chart Tools for .Net** software are supplied in complete source. In order to save space, they have not been pre-compiled which means that many of the intermediate object files needed to view the main form are not present. This means that **ChartView** derived control will not be visible on the main Form if you attempt to view the main form before the project has been compiled. The default state for all of the example projects should be the Start Page. Before you do view any other file or form, do a build of the project. This will cause the intermediate files to be built. If you attempt to view the main Form before building the project, Visual Studio sometimes decides that the **ChartView** control placed on the main form does not exist and deletes it from the project.

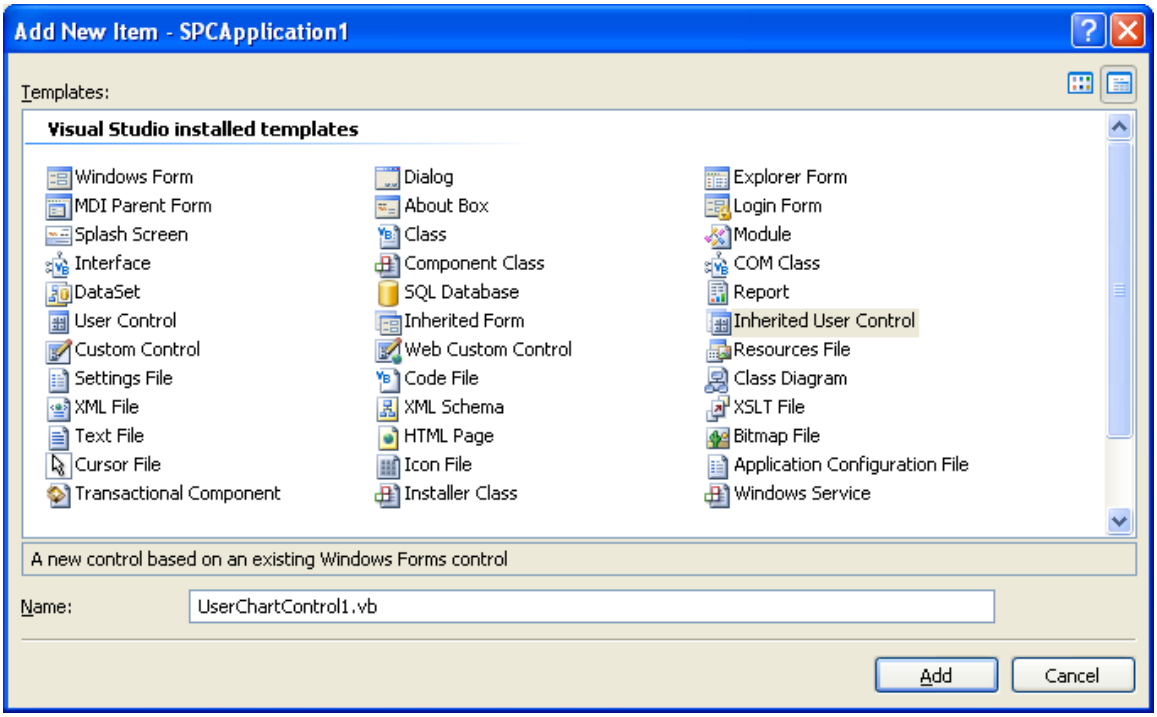
The primary view class of the QCSPCChart library is the ChartView class. The ChartView class derives from the .Net System.Windows.Forms.UserControl class. It has the properties and methods of the underlying UserControl class.

Follow the following steps in order to incorporate the QCSPCChart classes into your program. This is not the only way to add charts to an application. In general, any technique that works with UserControl derived classes will work. We found the technique described below to be the most flexible.

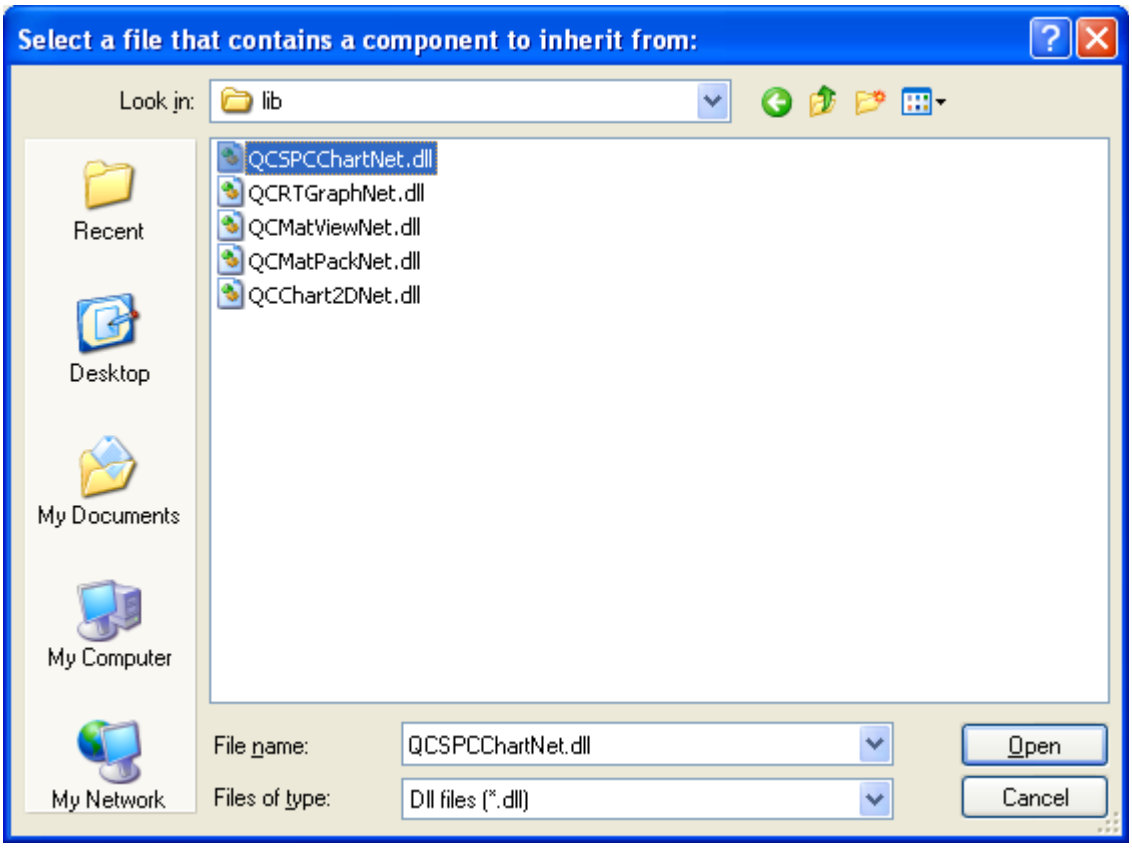
Visual Basic for *.Net*

If you do not already have an application program project, create one using the Visual Studio project wizard (File | New | Project | Visual Basic Projects | Windows Application). On the left, select a project type of Visual Basic Projects. Give the project a unique name (our version of this example is SPCApplication1). You will end with a basic Form based application. For purposes of this example, the chart will placed in the initial, default form.

5 Add a User Control class to the project (**Project | Add User Control**). Enter a class name of **UserChartControl1**. Select the template Inherited User Control. We use *the Inherited User Control* because it makes it easier to specify one of our SPC Chart types as the base class of the user control. The VB Inherits clause for a inherited user control shows up in the normally hidden UserChartControl1.Designer.vb file.

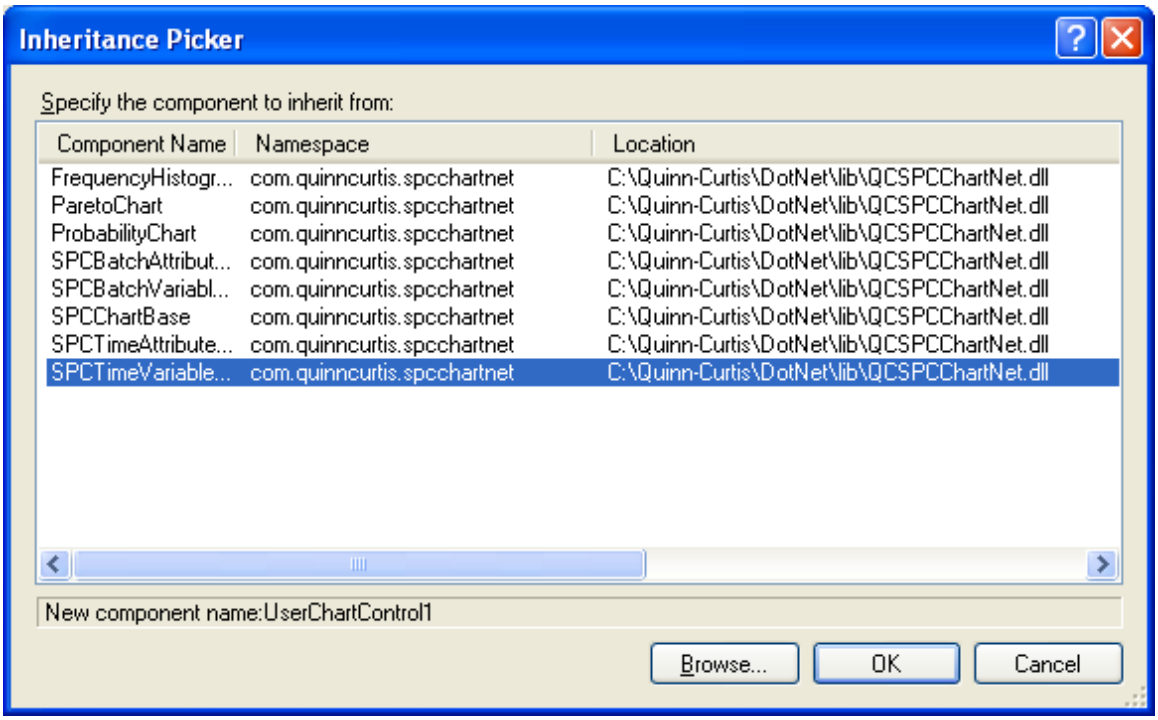


5 When you click Add, you will see the Inheritance Picker. Select Browse, browse to the Quinn-Curtis\DotNet\lib folder, and select the QCSPCChart.DLL file and select Open.



5 Select the **SPC Chart** component you want to inherit from. It should come from the following list.

5 SPCTimeVariableControlChart
5 SPCTimeAttributeControlChart
5 SPCBatchVariableControlChart
5 SPCBatchAttributeControlChart
5 FrequencyHistogramChart
5 ProbabilityChart
5 ParetoChart



5 Select OK. This will create a class named **UserChartControl1**, derived from **SPCTimeVariableControlChart** , and add it to the project. It also adds the QCChart2DNet.DLL and QCSPCChartNet.DLL files to the References section of the project.

*Important Note for VB programmers using VS 2005 or 2008

Starting with Visual Basic in VS 2005, when you use the project option to **Add User Control** to a project, where you intend to change the Inherit **UserControl** line to Inherit **ChartView**, you end up with TWO new VB files, instead of just one. The first is UserChartControl1.vb file, as described above. But it no longer contains the Inherits statement. Instead, the Inherit statement is found in the second file, UserChartControl1.Designer.vb. For some perverse reason this file is HIDDEN by default. You must explicitly select the **Show All Files** option of the Solution Explorer (second button from the left at the top of the Solution Explorer). Now you will see the UserChartControl1.Designer.vb file under the UserChartControl1.vb file in the Solution Explorer. Select the UserChartControl1.Designer.vb file to see how the Inherits statement is used. Normally you don't edit the UserChartControl1.Designer.vb file.

5 ***Critical Step:*** Make sure you add the following lines to the top of the UserChartControl1.vb code to resolve the **QCChart2D**, **QCSPCChart** and other graphics classes used in the example.

```
Imports System.Drawing
Imports System.Drawing.Drawing2D
Imports com.quinncurtis.chart2dnet
Imports com.quinncurtis.spcchartnet
```

5 Build the Solution (**Build | Build Solution**). This will compile the **UserChartControl1** class and make it accessible as a component on the Toolbox. If the project fails to compile you need to go back and check the previous steps.

You can create as many User Controls as your application requires. Each custom chart control will inherit from the **com.quinncurtis.chart2dnet.ChartView control. Or**

5 (Optional) You can create inherited controls from the **UserChartControl1** class that you already created. Create an inherited control by selecting **Project | Add Inherited Control**. Give the inherited control a unique name, i.e. **UserChartInheritedControl1**. When you select Open, choose **UserChartControl1** in the Inheritance Picker. The result is new control added to the project. Build the solution and the **UserChartInheritedControl1** control is added to the Toolbox in addition to the **UserChartControl1**.

5 Look at the **UserChartControl1** class. The chart is created in the **InitializeGraph** method. Until this method is called, the **UserChartControl1** appears as an empty shell. Sometimes it helps to call this method from somewhere outside of the class to avoid problems associated debugging errors in user controls at design time. Click on the UserChartControl1 form in design mode and a load event will be added to the code. You can add the InitializeGraph call there.

```
Private Sub UserChartControl1_Load(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles MyBase.Load
        InitializeChart()
End Sub
```

Go to the main form, **Form1**. Go to the toolbox and select the **UserChartControl1** from the Windows Forms list. Drop it onto the main form and size it. This will automatically create an instance of the **UserChartControl1** class and initialize it.

5 Define the chart by customizing the UserChartControl1.InitializeChart method. See the actual SPCApplication1.UserChartControl1.vb file for all of the actual code.

```
Public Sub InitializeChart()
   '  SPC variable control chart type
   Dim charttype As Integer = SPCControlChartData.MEAN_RANGE_CHART
   ' Number of datapoints in the view
   Dim numdatapointsinview As Integer = 17
.
.
.
End Sub 'InitializeChart
```

5 You should be able to compile the project without error.

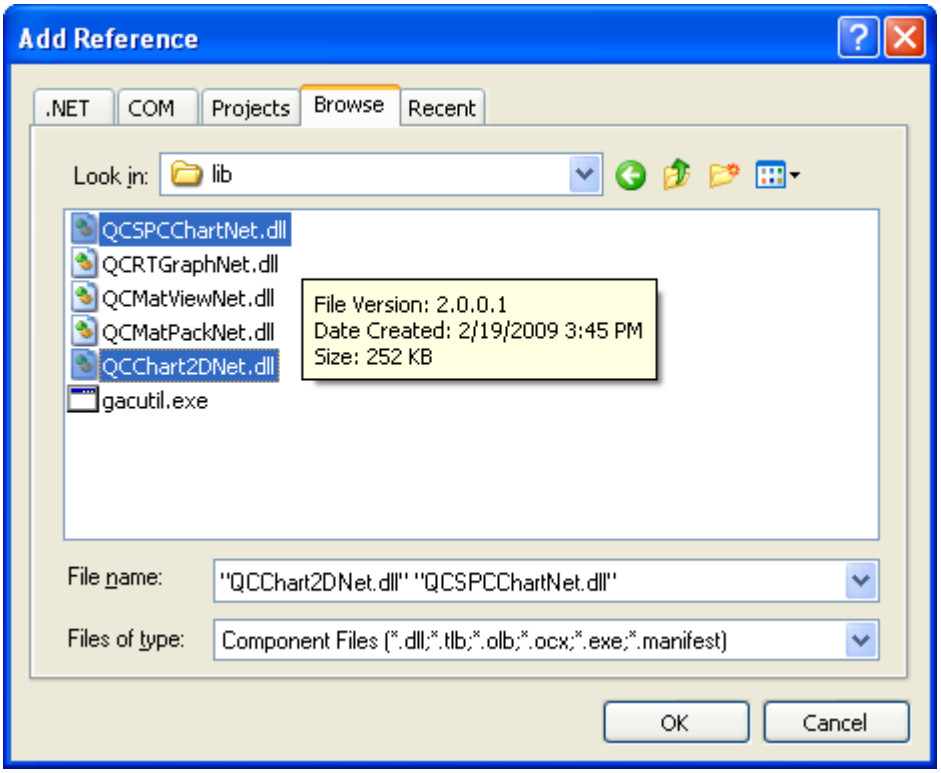
- You should now be able to compile, run and view the entire project. Any changes you make in the **UserChartControl1** form is reflected in the application. If you still have problems go back and study the many example programs we have provided.

Visual C# for *.Net*

.If you do not already have an application program project, create one using the Visual Studio project wizard (File | New | Project | Visual C# Projects | Windows Application). On the left, select a project type of Visual C# Projects. Give the project a unique name (our version of this example is SPCApplication1). You will end with a basic Form based application. For purposes of this example, the chart is placed in the initial, default form.

- Add a User Control class to the project (**Project | Add User Control**). Enter a class name of **UserChartControl1**.

- Right click on Reference in the Solution Explorer window and select **Add Reference**. Browse to the Quinn-Curtis/DotNet/lib subdirectory and select and add ***BOTH*** the **QCSPCChartNet.DLL** and **QCChart2DNet**.**DLL**.



View the UserChartControl1.cs code. Change the base class of UserChartControl1 to one of the SPC Chart classes derived from com.quinncurtis.chart2dnet.ChartView. These are:

- SPCTimeVariableControlChart
- SPCTimeAttributeControlChart
- SPCBatchVariableControlChart
- SPCBatchAttributeControlChart
- FrequencyHistogramChart
- ProbabilityChart
- ParetoChart

This adds a local version of the control to the project. The C# form code should now look like:

```
using System;
using System.Collections.Generic;
using System.ComponentModel;
using System.Drawing;
using System.Data;
using System.Text;
using System.Windows.Forms;
using System.Drawing.Drawing2D;
using com.quinncurtis.chart2dnet;
using com.quinncurtis.spcchartnet;

namespace SPCApplication1
{
    public partial class UserChartControl1 :
.quinncurtis.spcchartnet.SPCTimeVariableControlChart
    {
        public UserChartControl1()
        {
            InitializeComponent();
        }


    }
}
```

Note that the file uses a class modifier of *partial*. This means that there is more code associated with the class in the related UserControlChart1.Designer.cs file. Normally you will not need to edit that file.

- ***Critical Step:*** Make sure you add the following lines to the top of the **UserChartControl1.cs** code to resolve the **QCSPCChart** and other graphics classes used in the example.

```
using System.Drawing;
using System.Drawing.Drawing2D;
using com.quinncurtis.chart2dnet;
using com.quinncurtis.spcchartnet;
```

- Build the Solution (**Build | Build Solution**). This will compile the **UserChartControl1**class and make it accessible as a component on the Toolbox. If the project fails to compile, go back and check the previous steps.

You can create as many custom chart controls as your application requires. Each custom chart control will inherit from one of the SPC chart classes listed above.

5 Right click on the **UserChartControl1** class form and view the underlying C# code. We placed all of the chart customization code in the **InitializeGraph** method. Until this method is called, the **UserChartControl1**class appears as an empty shell. Your can call this method from the **UserChartControl1**class constructor;

```
public UserChartControl1()
{
    // This call is required by the Windows.Forms Form Designer.
    InitializeComponent();

    // TODO: Add any initialization after the InitForm call
    // Have the chart fill parent client area
    this.Dock = DockStyle.Fill;
    // Define and draw chart
    InitializeChart();
}
```

or from somewhere outside of the class to avoid problems associated debugging errors in user controls at design time.

5 Go to the main form, **Form1**. You can use either of the two following method to place the **UserChartControl1**class on the form.

1. In the Form1 source file, add a variable of type **UserChartControl1** in the declaration section, and in the Form1 constructor, instantiate the class and add it to the Form1 controls list:

or

2. Go to the toolbox and select the **UserChartControl1** from the Windows Forms list. Drop it onto the main form and size it.

5 Define the chart by customizing the **UserChartControl1.InitializeChart** method. See the SPCApplication1.UserChartControl1.cs file for the complete code listing.

```
ChartCalendar startTime = new ChartCalendar();
// The time increment between adjacent subgroups
int timeincrementminutes = 15;
// Number of samples per sub group
int numsamplespersubgroup = 5;

.
.
.

public void InitializeChart()
{
    //  SPC variable control chart type
    int charttype = SPCControlChartData.MEAN_RANGE_CHART;

    // Number of datapoints in the view
    int numdatapointsinview = 17;
```

```
        // Initialize the SPCTimeVariableControlChart
        this.InitSPCTimeVariableControlChart(charttype,
            numsamplespersubgroup, numdatapointsinview, timeincrementminutes);
        this.HeaderStringsLevel = SPCControlChartData.HEADER_STRINGS_LEVEL1;

       // Set the strings used in the header section of the table
        this.ChartData.Title = "Variable Control Chart (X-Bar & R)";
        this.ChartData.PartNumber = "283501";
        this.ChartData.ChartNumber="17";
        this.ChartData.PartName= "Transmission Casing Bolt";
        this.ChartData.Operation = "Threading";

        // Display the Sampled value rows of the table
        this.EnableInputStringsDisplay= true;
        // Display the Sampled value rows of the table
        this.EnableCategoryValues= true;
        // Display the Calculated value rows of the table
        this.EnableCalculatedValues= true;
        // Display the total samples per subgroup value row
        this.EnableTotalSamplesValues= true;
        // Display the Notes row of the table
        this.EnableNotes= true;
        // Display the time stamp row of the table
        this.EnableTimeValues = true;
            .
            .
            .
}
```

5 You should be able to compile the project without error. No chart will be visible yet.

5 You should now be able to compile, run and view the entire project. Any changes you make in the **UserChartControl1** form will be reflected in the application. If you still have problems go back and study the many example programs we have provided.

13. Using SPC Control Chart Tools for .Net to Create Web Applications

There are two ways you can integrate the QCSPCChart library in your web pages: the first is to serve up an image file created using QCSPCChart from the server; and the second is to actually embed a QCSPCChart UserControl, derived from our ChartView class, in the HTML web page.

In the first method, you use a Image component in either a HTML web page, or in an ASP.Net page. The source URL for the image component can either be an image file, or a URL address to an ASP page that serves up the image file as a stream. The QCSPCChart library includes a BufferedImage class that renders a ChartView chart as a memory bitmap and will output that image to a file or a stream. The image file or stream can be in any image format supported by the .Net System.Drawing.Imaging.ImageFormat class.

The second method, embedding a QCSPCChart ChartView derived object in an HTML page, is made possible because we eliminated the license file from the software. There was no way to check the license file from a control embedded in an HTML page without generating exceptions that would invalidate the control. We aren't sure what browsers support this, other than Microsoft Internet Explorer. In order to guarantee the necessary security clearance to run in the browser you must install our QCChart2DNet and QCSPCChartNet.DLL libraries in the GAC of the client computer – more on that later.

Included with the software is the complete source to the two web applications we have running on our web site at:

http://quinn-curtis.com/SPCWebApplication1/HTMLPage1.htm

http://quinn-curtis.com/SPCWebApplication2/HTMLPage1.htm

The source is found at the following locations.

[C#]

Quinn-Curtis\DotNet\QCSPCChart\Visual CSharp\examples\Asp.Net\SPCWebApplication1 Quinn-Curtis\DotNet\QCSPCChart\Visual Csharp\examples\Asp.Net\SPCWebApplication2

[VB]

Quinn-Curtis\DotNet\QCSPCChart\Visual Basic\examples\Asp.Net\VBSPCWebApplication1 Quinn-Curtis\DotNet\QCSPCChart\Visual Basic\examples\Asp.Net\VBSPCWebApplication2

ASP.Net Programs can run on the built-in VS 2005 Server

Starting with VS 2005, our ASP.Net example programs can run and be debugged locally under the built-in web server that ships as part of VS 2005 development system. Nothing special needs to be done. Just load the project and run. Each project is setup to display and run a local copy of a file named HTMLPage1.htm.

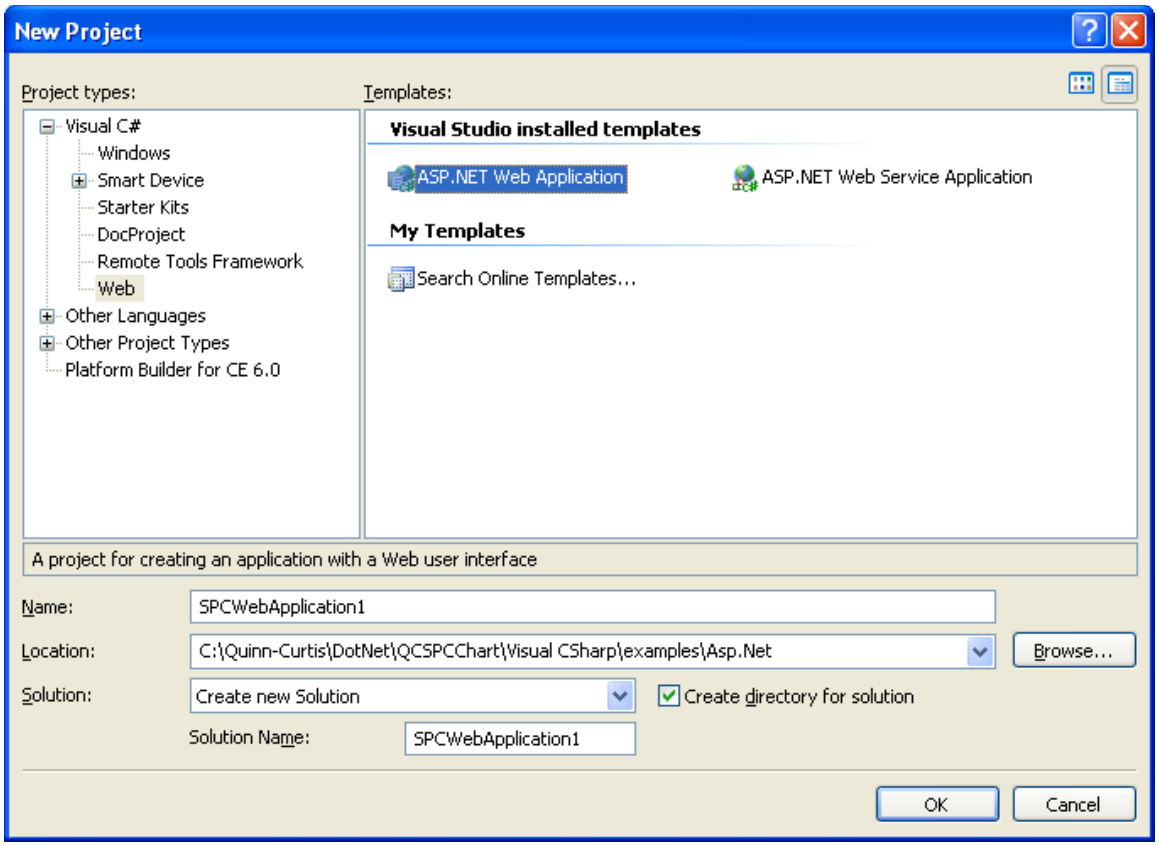
Start by creating your graph in a Windows form-based application

We strongly suggest that you develop and finalize the details of your chart by first creating it in a simple Windows form-based application. It is much easier to debug a .Net Windows form-based application than it is an Asp.Net application. Once you finalize the look of the graph, create the shell of the Asp.Net application, and move the chart building code from the Windows form-based application into the Asp.Net application

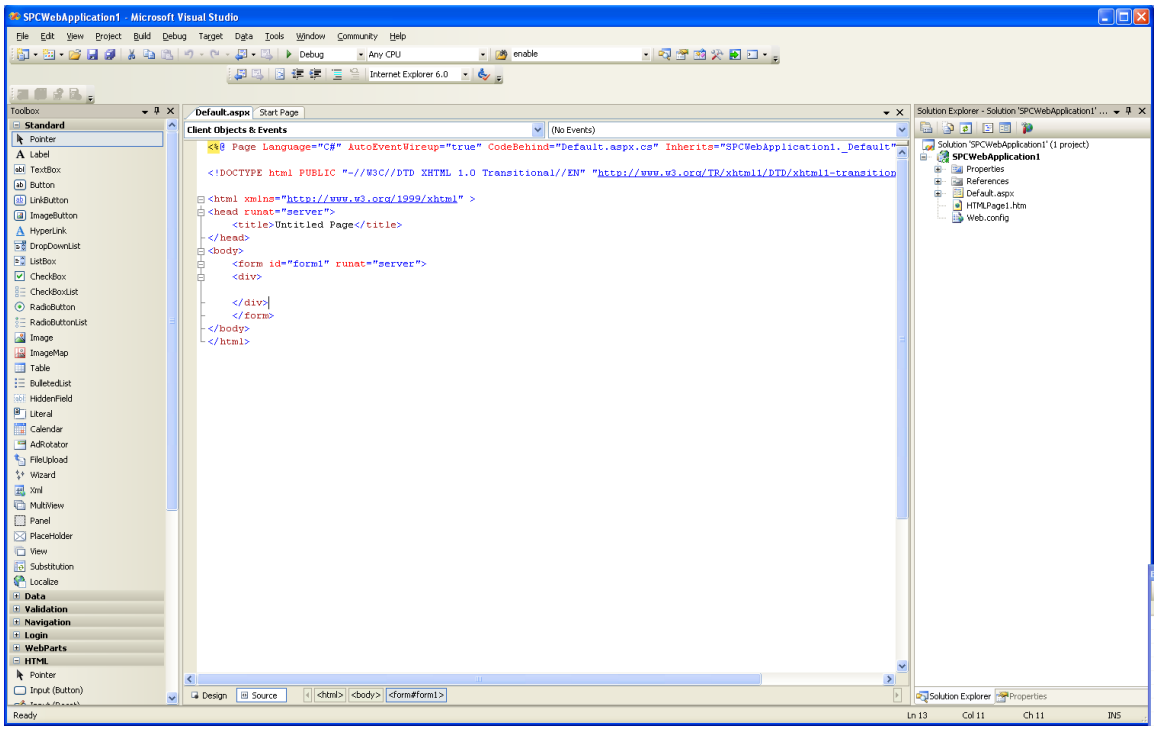
On Demand Creation of QCSPCChart Images from a Server

Visual C# for *.Net*

If you do not already have an application program project, create one using the Visual Studio project wizard (File | New | Project | Visual C# Projects | ASP.Net Web Application). On the left select a project type of Visual C# Projects. Give the project a unique name (our version of this example is SPCWebApplication1).



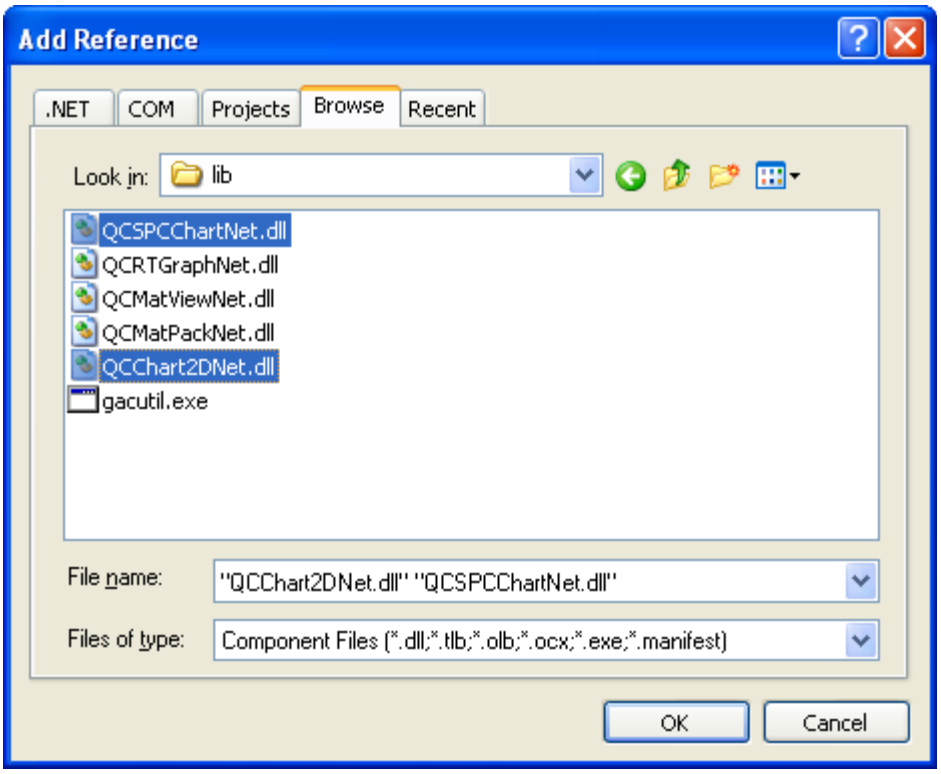
You will end with a basic WebForm based application with one System.Web.UI.Page derived form (Default.aspx by default). For purposes of this example, the chart will placed in the initial, default form. Assume that you want to make an ASP.Net application that streams an image file to an image component in a web page.



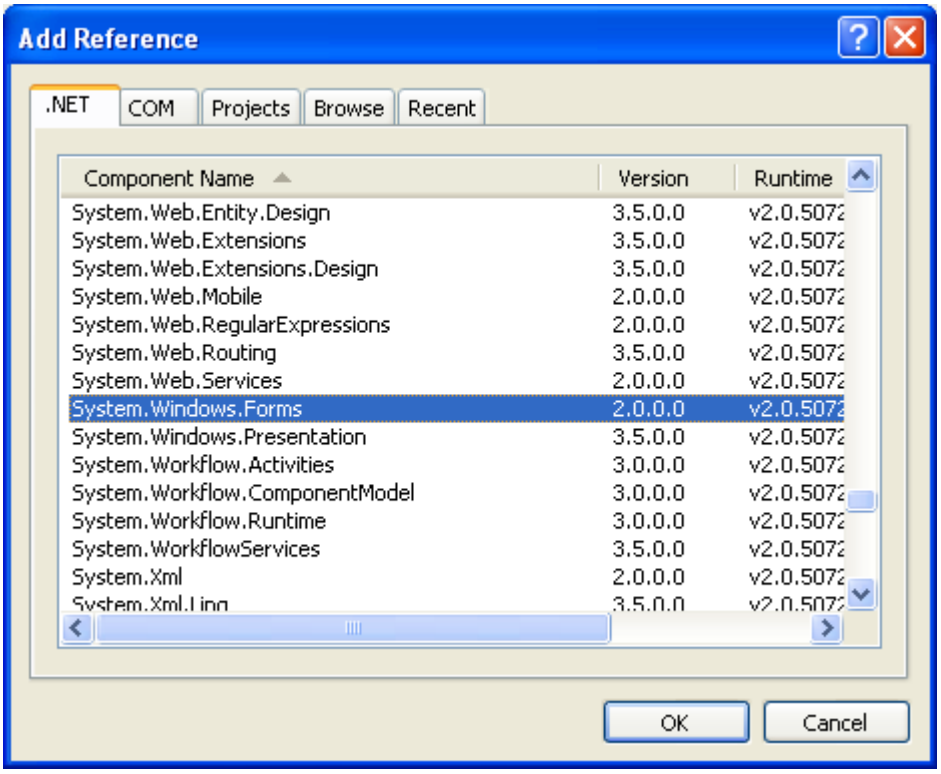
You do not need to add anything to the Default.aspx page. Right click on the page and select View Code. This brings up the code behind file (Default.aspx.cs) for the Default.aspx page. Add the following references in the using section at the top of the Default.aspx.cs file:

```
using System.Drawing;
using System.Drawing.Drawing2D;
using System.Drawing.Imaging;
using com.quinncurtis.chart2dnet;
using com.quinncurtis.spcchartnet;
```

5. Right click on Reference in the Solution Explorer window and select **Add Reference**. Browse to the Quinn-Curtis/DotNet/lib subdirectory and select the **QCChart2DNet.DLL** and **QCSPCChartNet.DLL**.



5 Also, add **System.Windows.Forms.dll** from the .Net list box.



After these initial steps you should be able to compile the basic program shell.

Add a method that makes the chart and returns a SPCTimeVariableControlChart object it could also be SPCBatchVariableControlChart, SPCTimeAttributeControlChart or SPCBatchAttributeControlChart) of the chart. In the example below, this is the function GetInitializeChart. It has arguments that that specify the desired height and width for the chart.

```
using System;
using System.Data;
using System.Configuration;
using System.Collections;
using System.Web;
using System.Web.Security;
using System.Web.UI;
using System.Web.UI.WebControls;
using System.Web.UI.WebControls.WebParts;
using System.Web.UI.HtmlControls;
using System.Drawing;
using System.Drawing.Drawing2D;
using System.Drawing.Imaging;
using com.quinncurtis.chart2dnet;
using com.quinncurtis.spcchartnet;


namespace SPCWebApplication1
{
    public partial class _Default : System.Web.UI.Page
    {
        ChartCalendar startTime = new ChartCalendar();
        // The time increment between adjacent subgroups
        int timeincrementminutes = 15;

        private void Page_Load(object sender, System.EventArgs e)
        {
            // Put user code to initialize the page here
            // Get Input from HTML ASP page request
            String widthstring = Request.Params.Get(0);
            String heightstring = Request.Params.Get(1);

            int imagewidth = int.Parse(widthstring);
            int imageheight = int.Parse(heightstring);
            int options = 15; // enables all options
            SPCTimeVariableControlChart chartVu =
                GetInitializeChart(imagewidth, imageheight, options);
            // Stream chart back as a JPeg image
            BufferedImage chartimage = new BufferedImage(chartVu,
                ImageFormat.Jpeg);
            // get your binary image data here
            Response.ContentType = "image/jpeg";
            chartimage.SaveImage(Response.OutputStream);
            chartVu.Dispose();
        }

        private SPCTimeVariableControlChart GetInitializeChart(int imagewidth, int imageheight, int
options)
        {
            SPCTimeVariableControlChart chartVu = new SPCTimeVariableControlChart();
            chartVu.Size = new Size(imagewidth, imageheight);
            InitializeSPCChart(chartVu, options);
            return chartVu;
        }

        private void InitializeSPCChart(SPCTimeVariableControlChart chartVu, int options)
        {
```

```
    //  SPC variable control chart type
    int charttype = SPCControlChartData.MEAN_RANGE_CHART;
    // Number of samples per sub group
    int numsamplespersubgroup = 5;
    // Number of datapoints in the view
    int numdatapointsinview = 17;
    int[] masks = { 1, 2, 4, 8 };

    bool headersOption = ((options & masks[0]) != 0);
    bool sampledValueOption = ((options & masks[1]) != 0);
    bool calculatedValueOption = ((options & masks[2]) != 0);
    bool histogramOption = ((options & masks[3]) != 0);


    // Initialize the SPCTimeVariableControlChart
    chartVu.InitSPCTimeVariableControlChart(charttype,
        numsamplespersubgroup, numdatapointsinview, timeincrementminutes);

    chartVu.HeaderStringsLevel = SPCControlChartData.HEADER_STRINGS_LEVEL2;

    // Set the strings used in the header section of the table
    chartVu.ChartData.Title = "Variable Control Chart (X-Bar & R)";
    chartVu.ChartData.PartNumber = "283501";
    chartVu.ChartData.ChartNumber = "17";
    chartVu.ChartData.PartName = "Transmission Casing Bolt";
    chartVu.ChartData.Operation = "Threading";
    chartVu.ChartData.TheOperator = "Roger Bacon";
    chartVu.ChartData.Machine = "AB 276";
    chartVu.GraphStartPosX = 0.175;
    chartVu.GraphStopPosX = 0.89;


    // Display the Sampled value rows of the table
    chartVu.EnableInputStringsDisplay = headersOption;
    // Display the Sampled value rows of the table
    chartVu.EnableCategoryValues = sampledValueOption;
    // Display the Calculated value rows of the table
    chartVu.EnableCalculatedValues = calculatedValueOption;
    // Display the total samples per subgroup value row
    chartVu.EnableTotalSamplesValues = calculatedValueOption;
    // Display the Notes row of the table
    chartVu.EnableNotes = false;
    chartVu.EnableTotalSamplesValues = false;
    // Display the time stamp row of the table
    chartVu.EnableTimeValues = sampledValueOption | calculatedValueOption;
    //  frequency histogram for both charts
    chartVu.PrimaryChart.DisplayFrequencyHistogram = histogramOption;
    chartVu.SecondaryChart.DisplayFrequencyHistogram = histogramOption;

    SimulateData(chartVu);

    // Calculate the SPC control limits for both graphs of the current SPC chart (X-Bar R)
    chartVu.AutoCalculateControlLimits();
    // Scale the y-axis of the X-Bar chart to display all data and control limits
    chartVu.AutoScalePrimaryChartYRange();
    // Scale the y-axis of the Range chart to display all data and control limits
    chartVu.AutoScaleSecondaryChartYRange();
    // Rebuild the chart using the current data and settings
    chartVu.RebuildChartUsingCurrentData();

}

public void SimulateData(SPCTimeVariableControlChart chartVu)
{
    for (int i = 0; i < 200; i++)
    {
        ChartCalendar timestamp = (ChartCalendar)startTime.Clone();
        // Use the ChartData sample simulator to make an array of sample data
        DoubleArray samples = chartVu.ChartData.SimulateMeasurementRecord(30, 10);
        // Add the new sample subgroup to the chart
        chartVu.ChartData.AddNewSampleRecord(timestamp, samples);
```

```
            // increment simulated time by timeincrementminutes minutes
            startTime.Add(ChartObj.MINUTE, timeincrementminutes);
        }
    }
}
}
```

5. Modify the Page_Load method that was included by default when the behind code page was created. In the example below, parameters that were appended to the ASP page request are retrieved using the Request.Params.Get method. The values define the size and data values of the graph. This is just one way to pass data from the HTML page to the ASP page. Using the behind code page you can query some database and get the data values from there, without passing the data through the HTML page. Once the chart is create and available as a **ChartView** *derived* object, use the **BufferedImage** class to render the chart as a JPEG file and stream the image back in the response stream of the requesting HTML page.

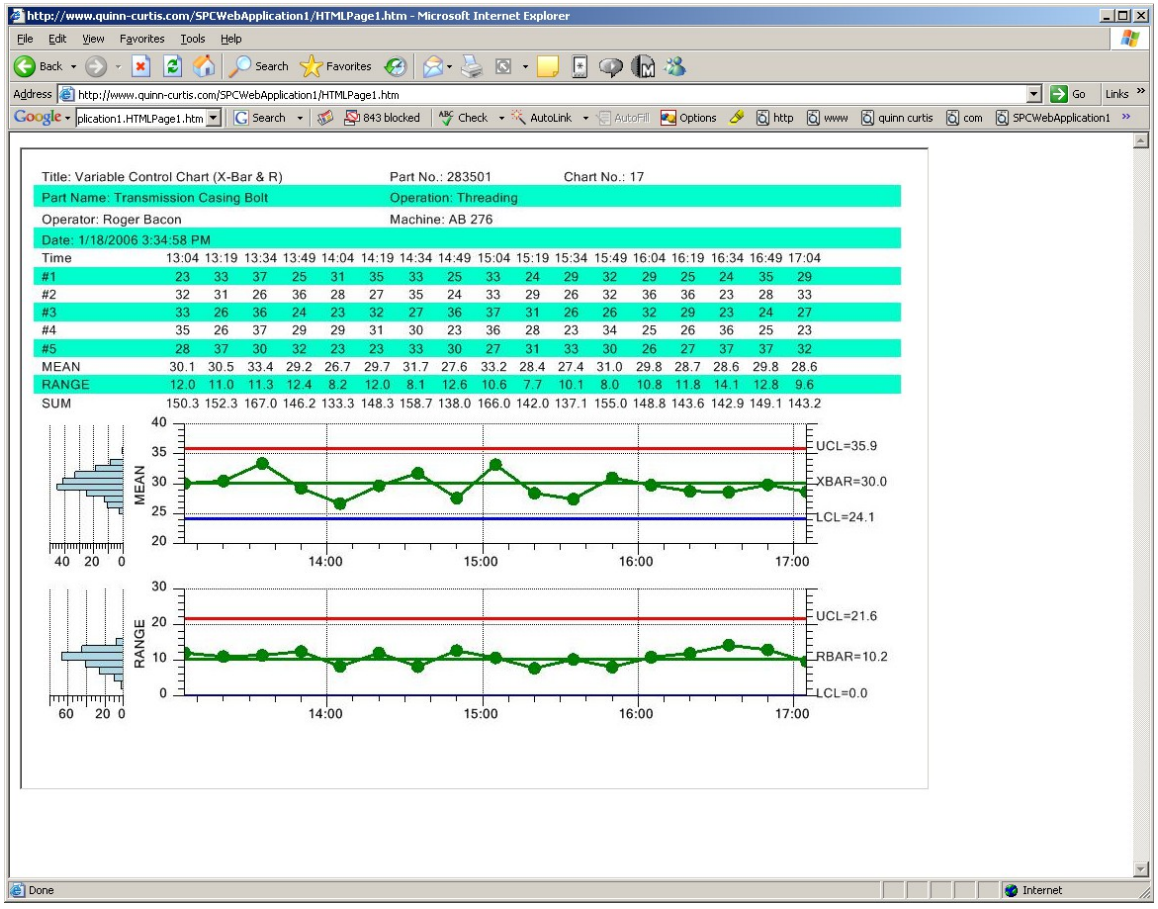
```
private void Page_Load(object sender, System.EventArgs e)
{
    // Put user code to initialize the page here
    // Get Input from HTML ASP page request
    String widthstring = Request.Params.Get(0);
    String heightstring = Request.Params.Get(1);

    int imagewidth = int.Parse(widthstring);
    int imageheight = int.Parse(heightstring);
    int options = 15; // enables all options
    SPCTimeVariableControlChart chartVu =
     GetInitializeChart(imagewidth, imageheight, options);
    // Stream chart back as a JPeg image
    BufferedImage chartimage = new BufferedImage(chartVu,
        ImageFormat.Jpeg);
    // get your binary image data here
    Response.ContentType = "image/jpeg";
    chartimage.SaveImage(Response.OutputStream);
    chartVu.Dispose();
}
```

Build the Solution (**Build | Build Solution**) and resolve any errors that might have crept in. This example was not designed to be a standalone application.

5. You will probably want to create a HTML page to host the call to the ASP page. This can be done using FrontPage, a simple editor and the Visual Studio IDE. The complete source to a <body> for the HTMLPage1.htm is seen below.

```
.
.
.
    <body>
        <p>
            <iframe name="I1" width="920" height="650" src="http://quinn-
curtis.com/SPCWebApplication1/Default.aspx?WIDTH=880&HEIGHT=610">
Your browser does not support inline frames or is currently configured not to
display inline frames.</iframe>
        </p>
    </body>
```

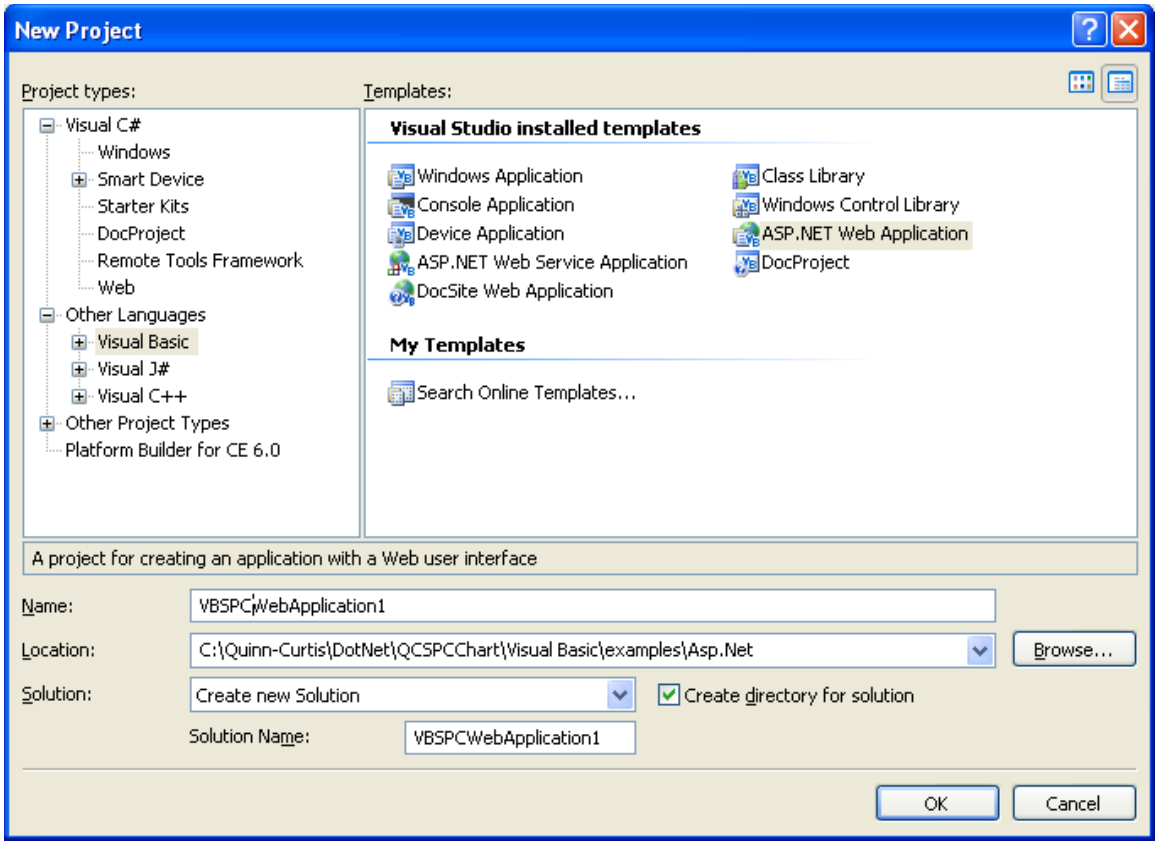
.



5 Another method is to use two WebForms in the ASP application. The first form is setup much like the previous example. The aspx page contains nothing, and the aspx.cs behind code page does all the work, defining a chart and streaming the result back as a JPEG image. The second WebForm page hosts a collection of Web controls place on the aspx page. One of these Web controls is an Image web control. The behind code page for this WebForm connects the URL of the Image control to the first WebForm page, which does nothing be serve up charts. Our example SPCWebApplication2 uses this approach. The reason you might want to take this approach is that it is much easier to wire up the controls on a WebForm page using the aspx.cs behind code as opposed to doing it on an HTML page. The drawback is that the entire page redraws when anything is posted, causing a momentary flash when the chart is redraw. Using the HTML approach the chart redraws without the flash, making it a better method for real-time applications.

Visual Basic for *.Net*

If you do not already have an application program project, create one using the Visual Studio project wizard (File | New | Project | Visual Basic Projects | ASP.Net Web Application). On the left select a project type of Visual Basic Projects. Give the project a unique name (our version of this example is VBSPCWebApplication1). You will end with a basic WebForm based application with one System.Web.UI.Page derived form (Default.aspx by default). For purposes of this example, the chart will placed in the initial, default form. Assume that you want to make an ASP.Net application that streams an image file to an image component in a web page.

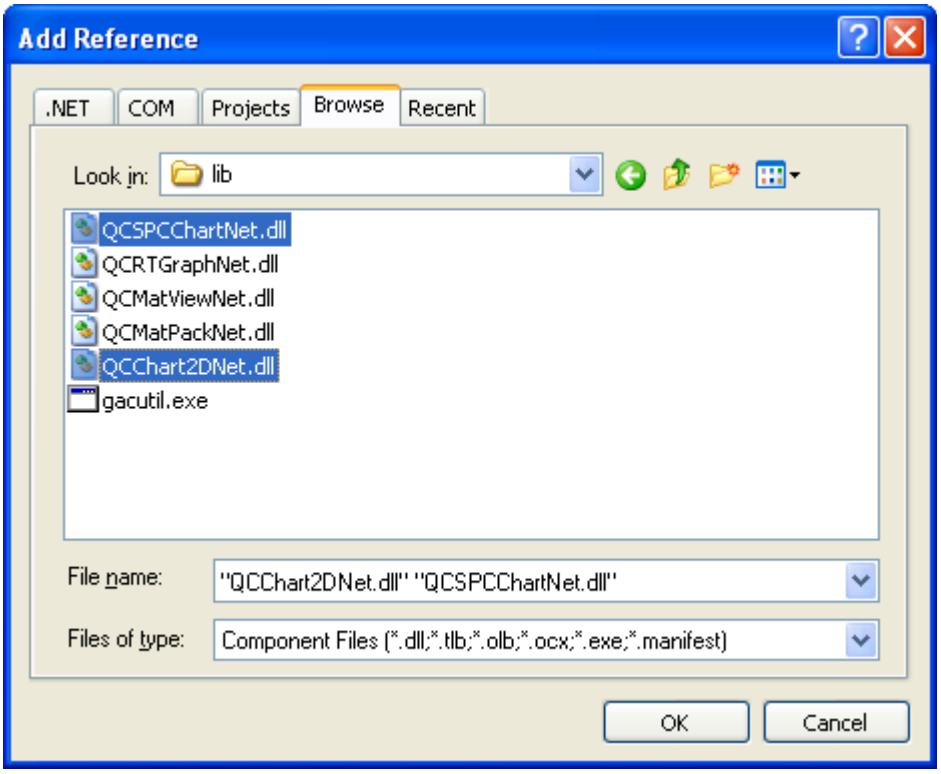


You do not need to add anything to the Default.aspx page. Right click on the page and select View Code. This brings up the code behind file (Default.aspx.vb) for the Default.aspx page. Add the following references in the using section at the top of the Default.aspx.vb file:

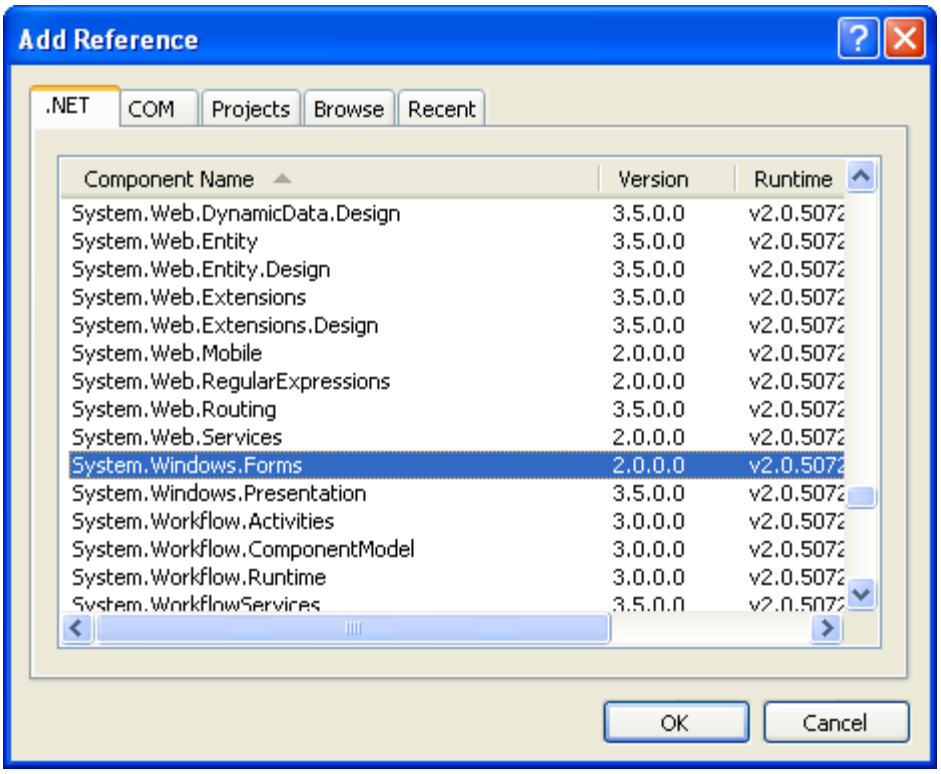
```
Imports System.Drawing
```

```
Imports System.Drawing.Drawing2D
Imports System.Drawing.Imaging
Imports com.quinncurtis.chart2dnet
Imports com.quinncurtis.spcchartnet
```

5 Right click on Reference in the Solution Explorer window and select **Add Reference**. Browse to the Quinn-Curtis/DotNet/lib subdirectory and select the **QCChart2DNet.DLL** and **QCSPCChartNet.DLL**.



5 Also add **System.Windows.Forms.dll** from the .Net list box.



After these initial steps, you should be able to compile the basic program shell.

Add a method that makes the chart and returns a SPCTimeVariableControlChart object it could also be SPCBatchVariableControlChart, SPCTimeAttributeControlChart or SPCBatchAttributeControlChart) of the chart. In the example below, this is the function GetInitializeChart. It has arguments that that specify the desired height and width for the chart.

```
Imports System.Drawing
Imports System.Drawing.Drawing2D
Imports System.Drawing.Imaging
Imports com.quinncurtis.chart2dnet
Imports com.quinncurtis.spcchartnet

Partial Public Class _Default
    Inherits System.Web.UI.Page

    Dim startTime As ChartCalendar = New ChartCalendar()
    Dim timeincrementminutes As Integer = 15

    Private Sub Page_Load(ByVal sender As System.Object, _
       ByVal e As System.EventArgs) Handles MyBase.Load
        'Put user code to initialize the page here
        ' Put user code to initialize the page here
        ' Get Input from HTML ASP page request
        Dim widthstring As [String] = Request.Params.Get(0)
        Dim heightstring As [String] = Request.Params.Get(1)

        Dim imagewidth As Integer = Integer.Parse(widthstring)
        Dim imageheight As Integer = Integer.Parse(heightstring)
```

```
        ' Turn on all options
        Dim options As Integer = 15

        Dim chartVu As SPCTimeVariableControlChart = GetInitializeChart(imagewidth, imageheight, options)
        ' Stream chart back as a JPeg image
        Dim chartimage As New BufferedImage(chartVu, ImageFormat.Jpeg)
        ' get your binary image data here
        Response.ContentType = "image/jpeg"
        chartimage.SaveImage(Response.OutputStream)
        chartVu.Dispose()

    End Sub


    Private Function GetInitializeChart(ByVal imagewidth As Integer, ByVal imageheight As Integer, ByVal
options As Integer) As SPCTimeVariableControlChart

        Dim chartVu As New SPCTimeVariableControlChart()
        chartVu.Size = New Size(imagewidth, imageheight)
        InitializeSPCChart(chartVu, options)
        Return chartVu
    End Function 'GetInitializeChart


    Private Sub InitializeSPCChart(ByVal chartVu As SPCTimeVariableControlChart, ByVal options As
Integer)
        '  SPC variable control chart type
        Dim charttype As Integer = SPCControlChartData.MEAN_RANGE_CHART
        ' Number of samples per sub group
        Dim numsamplespersubgroup As Integer = 5
        ' Number of datapoints in the view
        Dim numdatapointsinview As Integer = 17
        Dim masks() As Integer = {1, 2, 4, 8}

        Dim headersOption As Boolean = (options And masks(0)) <> 0
        Dim sampledValueOption As Boolean = (options And masks(1)) <> 0
        Dim calculatedValueOption As Boolean = (options And masks(2)) <> 0
        Dim histogramOption As Boolean = (options And masks(3)) <> 0


        ' Initialize the SPCTimeVariableControlChart
        chartVu.InitSPCTimeVariableControlChart(charttype, numsamplespersubgroup, numdatapointsinview,
timeincrementminutes)

        chartVu.HeaderStringsLevel = SPCControlChartData.HEADER_STRINGS_LEVEL2

        ' Set the strings used in the header section of the table
        chartVu.ChartData.Title = "Variable Control Chart (X-Bar & R)"
        chartVu.ChartData.PartNumber = "283501"
        chartVu.ChartData.ChartNumber = "17"
        chartVu.ChartData.PartName = "Transmission Casing Bolt"
        chartVu.ChartData.Operation = "Threading"
        chartVu.ChartData.TheOperator = "Roger Bacon"
        chartVu.ChartData.Machine = "AB 276"
        chartVu.GraphStartPosX = 0.175
        chartVu.GraphStopPosX = 0.89


        ' Display the Sampled value rows of the table
        chartVu.EnableInputStringsDisplay = headersOption
        ' Display the Sampled value rows of the table
        chartVu.EnableCategoryValues = sampledValueOption
        ' Display the Calculated value rows of the table
        chartVu.EnableCalculatedValues = calculatedValueOption
        ' Display the total samples per subgroup value row
        chartVu.EnableTotalSamplesValues = calculatedValueOption
        ' Display the Notes row of the table
        chartVu.EnableNotes = False
        chartVu.EnableTotalSamplesValues = False
        ' Display the time stamp row of the table
```

```
        chartVu.EnableTimeValues = sampledValueOption Or calculatedValueOption

        '  frequency histogram for both charts
        chartVu.PrimaryChart.DisplayFrequencyHistogram = histogramOption
        chartVu.SecondaryChart.DisplayFrequencyHistogram = histogramOption

        SimulateData(chartVu)

        ' Calculate the SPC control limits for both graphs of the current SPC chart (X-Bar R)
        chartVu.AutoCalculateControlLimits()
        ' Scale the y-axis of the X-Bar chart to display all data and control limits
        chartVu.AutoScalePrimaryChartYRange()
        ' Scale the y-axis of the Range chart to display all data and control limits
        chartVu.AutoScaleSecondaryChartYRange()
        ' Rebuild the chart using the current data and settings
        chartVu.RebuildChartUsingCurrentData()
    End Sub 'InitializeSPCChart


    Public Sub SimulateData(ByVal chartVu As SPCTimeVariableControlChart)
        Dim i As Integer
        For i = 0 To 199
            Dim timestamp As ChartCalendar = CType(startTime.Clone(), ChartCalendar)
            ' Use the ChartData sample simulator to make an array of sample data
            Dim samples As DoubleArray = chartVu.ChartData.SimulateMeasurementRecord(30, 10)
            ' Add the new sample subgroup to the chart
            chartVu.ChartData.AddNewSampleRecord(timestamp, samples)
            ' increment simulated time by timeincrementminutes minutes
            startTime.Add(ChartObj.MINUTE, timeincrementminutes)
        Next i
    End Sub 'SimulateData

End Class
```

5. Modify the Page_Load method that was included by default when the behind code page was created. In the example below, parameters that were appended to the ASP page request are retrieved using the Request.Params.Get method. The values define the size and data values of the graph. This is just one way to pass data from the HTML page to the ASP page. Using the behind code page you can query some database and get the data values from there, without passing the data through the HTML page. Once the chart is create and available as a **ChartView** *derived* object, use the **BufferedImage** class to render the chart as a JPEG file and stream the image back in the response stream of the requesting HTML page.

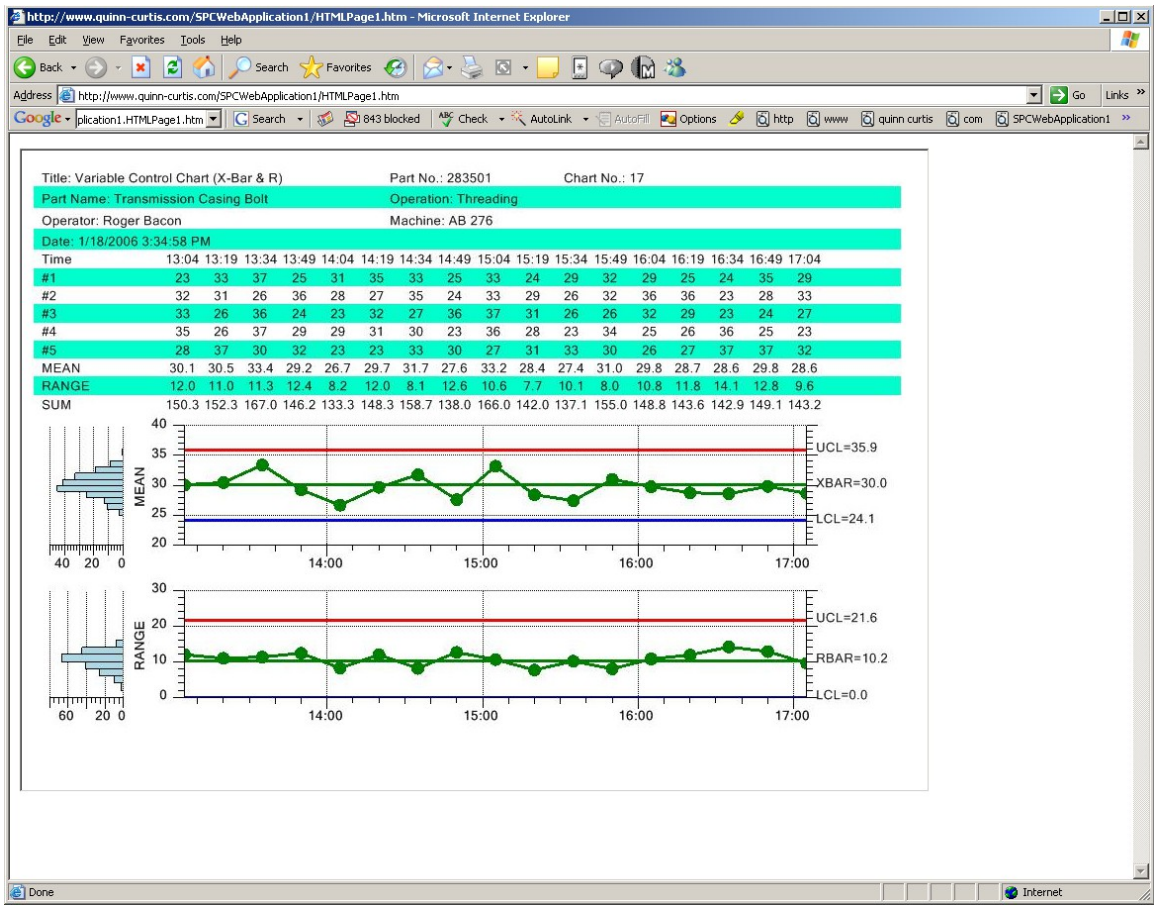
```
    Private Sub Page_Load(ByVal sender As System.Object, _
       ByVal e As System.EventArgs) Handles MyBase.Load
        'Put user code to initialize the page here
        ' Put user code to initialize the page here
        ' Get Input from HTML ASP page request
        Dim widthstring As [String] = Request.Params.Get(0)
        Dim heightstring As [String] = Request.Params.Get(1)

        Dim imagewidth As Integer = Integer.Parse(widthstring)
        Dim imageheight As Integer = Integer.Parse(heightstring)

        ' Turn on all options
        Dim options As Integer = 15

        Dim chartVu As SPCTimeVariableControlChart = GetInitializeChart(imagewidth, imageheight, options)
        ' Stream chart back as a JPeg image
```

```
        Dim chartimage As New BufferedImage(chartVu, ImageFormat.Jpeg)
        ' get your binary image data here
        Response.ContentType = "image/jpeg"
        chartimage.SaveImage(Response.OutputStream)
        chartVu.Dispose()

    End Sub
```

Build the Solution (**Build | Build Solution**) and resolve any errors that might have crept in. This example was not designed to be a standalone application.

5. You will probably want to create a HTML page to host the call to the ASP page. This can be done using FrontPage, a simple editor and the Visual Studio IDE. A simple HTML page that connects the URL address above to an HTML image tag appears below. The complete source to a <body> for the HTMLPage1.htm is seen below.

```
        .
        .
        .
<body>
            <p>
                    <iframe name="I1" width="920" height="650" src="Default.aspx?WIDTH=880&HEIGHT=610">
Your browser does not support inline frames or is currently configured not to display inline
frames.</iframe>
            </p>
</body>
                .
```



5. Another method is to use two WebForms in the ASP application. The first form is setup much like the previous example. The aspx page contains nothing, and the aspx.vb behind code page does all the work, defining a chart and streaming the result back as a JPEG image. The second WebForm page hosts a collection of Web controls place on the aspx page. One of these Web controls is an Image web control. The behind code page for this WebForm connects the URL of the Image control to the first WebForm page, which does nothing be serve up charts. Our example SPCWebApplication2 uses this approach. The reason you might want to take this approach is that it is much easier to wire up the controls on a WebForm page using the aspx.cs behind code as opposed to doing it on an HTML page. The drawback is that the entire page redraws when anything is posted, causing a momentary flash when the chart is redraw. Using the HTML approach the chart redraws without the flash, making it a better method for real-time applications.

Embedding a QCSPCChart Object into Internet Explorer *

* Special Note

This technique only works with the commercial version of the software. It will NOT work with the trial version of the software.

In order to embed a QCSPCChart object into Internet Explorer, the client must have the QCChart2DNet.DLL and QCSPCChartNet.DLL files installed in the system GAC (Global Assembly Cache). This gives the DLLs the necessary security clearance to run in a browser. Perform the following steps.

- Locate the Gacutil.exe (found in your Visual Studio installation) program and copy it to our Quinn-Curtis\DotNet\Lib.

- Run Gacutil.exe from the DOS prompt while you are in the Quinn-Curtis\DotNet\Lib directory using the following command line:

  Gacutil -i QCChart2DNet.DLL

  Gacutil -i QCSPCChartNet.DLL

You will find an endless source of information about the GAC on the web and there is no need to repeat it. Here is a starting point:

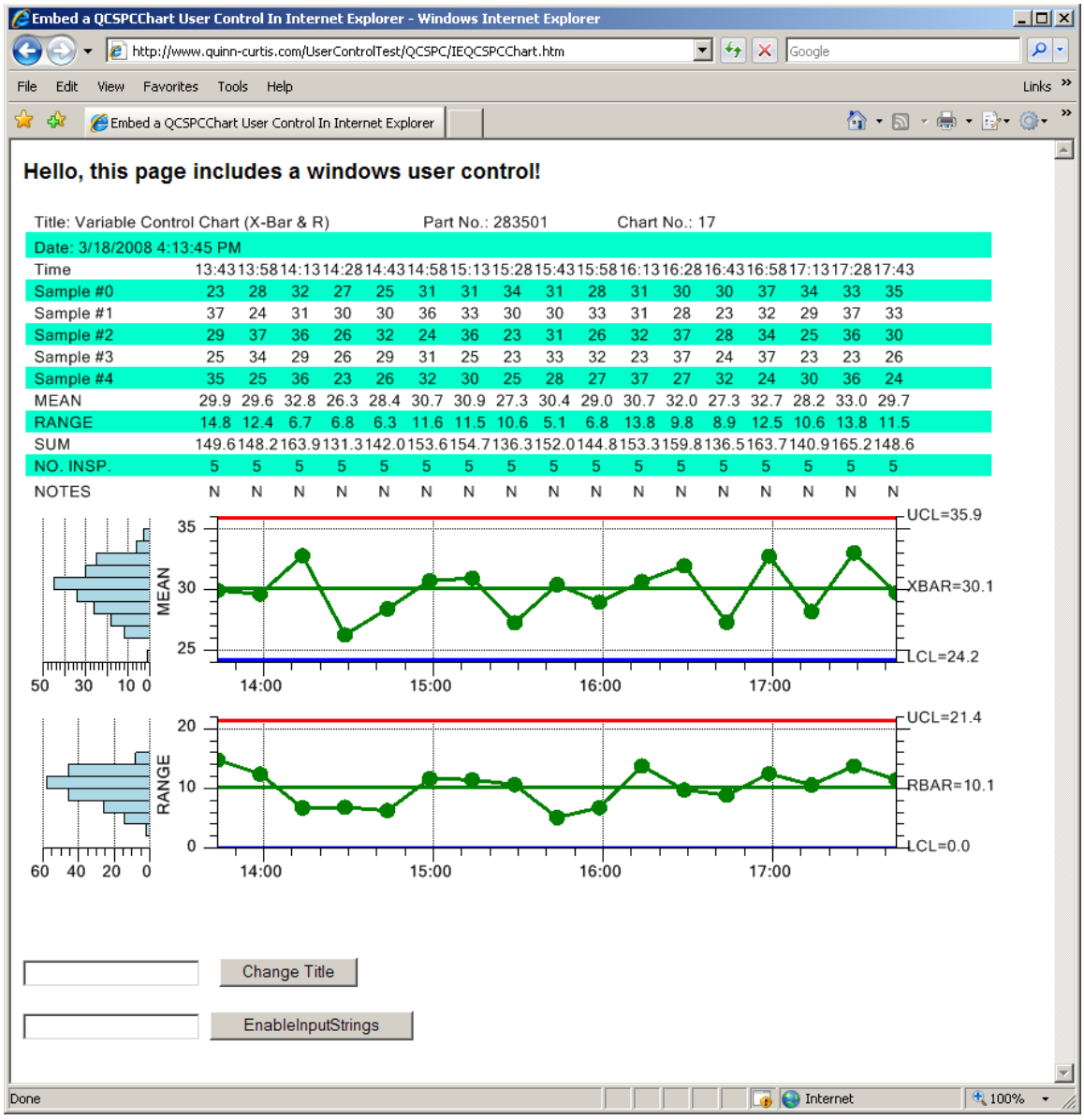
http://www.codeproject.com/dotnet/DemystifyGAC.asp

In general, you should not be installing any of our .Net DLL's in the system GAC, unless you have an overriding reason to so. In general, our .Net DLLs should just be distributed as part of an application program and would normally reside in the same folder as the application programs executable. One exception is if you expect a **QCSPCChart** derived UserControl to run in Internet Explorer. In that case the QCChart2DNet.DLL and QCSPCChartNet.DLL files must be installed as part of the GAC, so that it has the necessary security clearance, and so that IE can find it when it has to display the control.

If you have installed it correctly, you should be able to view the web page below that references a QCSPCChart derived user control.

http://www.quinn-curtis.com/UserControlTestRev2/QCSPC/IEQCSPCChart.htm

Once the QCSPCChartNet DLL has been successfully installed in the system GAC, you must create a **ChartView** derived **UserControl** that creates the chart you want to display in the browser. This can be done using either C# or VB. And you must create a HTML page that displays the chart, and provides whatever interaction you expect. The **ChartView** derived **UserControl** cannot do anything that would violate the security policy of the browser. This would include all forms of disk I/O, and anything in general that tries to access anything on the client computer.

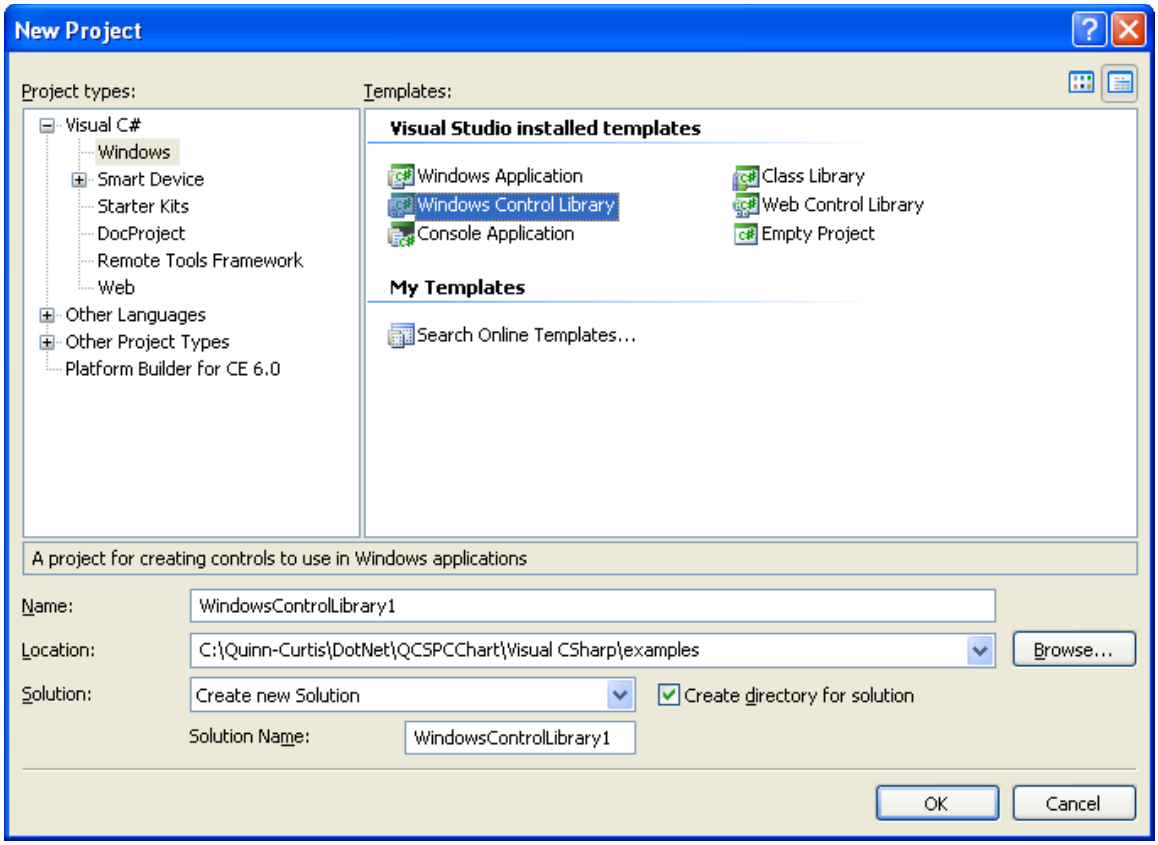


Visual C# - Create a Windows Control Library and User Control

You need to create a **ChartView** derived user control that defines your chart, and includes all of the properties that you need for interacting with your chart. This is done almost exactly the same as described in the previous chapter, **Using QCSPCChart for *.Net* to Create Windows Applications.** The difference is that instead of creating a .Net application, resulting in an exe file you can run from Windows, you are instead creating a Windows Control Library, which results in a DLL file. What you end up with is a user

control, not an executable program. The user control must be referenced in a specific way in an HTML file before you can display it. The basic steps for creating the **ChartView** derived control are described below.

Start by creating a Windows Control Library project, using the Visual Studio project wizard (**File | New | Project | Visual C# Projects | Windows Control Library**). On the left select a project type of **Visual C# Projects**. Give the project a unique name (our version of this example is **WindowsControlLibrary1**). You will end with the shell of a UserControl class with the name UserControl1. You will modify UserControl1 and turn it into an object derived from our ChartView object.



5 Right click on Reference in the Solution Explorer window and select **Add Reference**. Browse to the Quinn-Curtis/DotNet/lib subdirectory and select the two DLLs, **QCChart2DNet.DLL** and **QCSPCChartNet.DLL**.

5 View the **UserControl1.cs** code. Change the base class of **UserControl1** to **com.quinncurtis.spcchartnet.SPCTimeVariableControlChart** . The C# form code should now look like:

```
namespace WindowsControlLibrary1
```

```
{
            /// <summary>
            /// Summary description for UserControl1.
            /// </summary>
            public class UserControl1 : com com.quinncurtis.spcchartnet.SPCTimeVariableControlChart
            {
                public UserControl1()
                {
                    // This call is required by the Windows.Forms Form Designer.
                    InitializeComponent();

                    // TODO: Add any initialization after the InitForm call

                }
            }
}
```

5. ***Critical Step:*** Make sure you add the following lines to the top of the **UserChartControl1.cs** code to resolve the QCChart2D, QCSPCChart and other graphics classes used in the example.

```
using System.Drawing;
using System.Drawing.Drawing2D;
using com.quinncurtis.chart2dnet;
using com.quinncurtis.spcchartnet;
```

5. Build the Solution (**Build | Build Solution**). This will compile the **UserControl1** class and generate the WindowsControlLibrary1.DLL file. If the project fails to compile you need to go back and check the previous steps.

5. You can add as many custom chart controls as you need for the given HTML page you plan to display charts in. Each custom chart control will inherit from the **com.quinncurtis.spcchartnet.SPCTimeVariableControlChart** control. Or

5. (Optional) You can create inherited controls from the **UserChartControl1** class that you already created. Create an inherited control by selecting **Project | Add Inherited Control**. Give the inherited control a unique name, i.e. **UserInheritedControl1**. When you select Open, choose **UserControl1** in the Inheritance Picker. The result is new control added to the project. Build the solution and the **UserInheritedControl1** control will be added to the WindowsControlLibrary1.DLL in addition to the **UserControl1**.

5. View the **UserChartControl1.cs** underlying C# code. We placed all of the chart creation code in the **InitializeChart** method. This method is called in the **UserControl1** constructor, otherwise the **UserControl1** appears as an empty shell. Add whatever properties you need to get data from the HTML file into the chart control (**ChartTitleText** and **EnableInputStrings** in the example below.

```
using System;
using System.Collections.Generic;
using System.ComponentModel;
using System.Drawing;
using System.Data;
using System.Text;
using System.Windows.Forms;
using System.Drawing.Drawing2D;
using com.quinncurtis.chart2dnet;
```

```
using com.quinncurtis.spcchartnet;


namespace WindowsControlLibrary1
{
    public partial class UserControl1 : com.quinncurtis.spcchartnet.SPCTimeVariableControlChart
    {

        ChartCalendar startTime = new ChartCalendar();
        // The time increment between adjacent subgroups
        int timeincrementminutes = 15;

        public UserControl1()
        {
            // This call is required by the Windows.Forms Form Designer.
            InitializeComponent();

            // TODO: Add any initialization after the InitForm call
            // Have the chart fill parent client area
            this.Dock = DockStyle.Fill;
            // Define and draw chart
            InitializeChart();
        }


        ///<summary>
        /// Set/Get the chart title
        ///</summary>
        public string ChartTitleText
        {
            get { return this.ChartData.Title; }
            set
            {
                this.ChartData.Title = value;
                this.RebuildChartUsingCurrentData();
            }
        }

        ///<summary>
        /// Set/Get the input string flag
        ///</summary>
        public bool EnableInputStrings
        {
            get
            {
                return this.EnableInputStringsDisplay;
            }
            set
            {
                this.EnableInputStringsDisplay = value;
                this.RebuildChartUsingCurrentData();
            }
        }



        public void InitializeChart()
        {
            //  SPC variable control chart type
            int charttype = SPCControlChartData.MEAN_RANGE_CHART;
            // Number of samples per sub group
            int numsamplespersubgroup = 5;
            // Number of datapoints in the view
            int numdatapointsinview = 17;


            // Initialize the SPCTimeVariableControlChart
            this.InitSPCTimeVariableControlChart(charttype,
                numsamplespersubgroup, numdatapointsinview, timeincrementminutes);

            this.HeaderStringsLevel = SPCControlChartData.HEADER_STRINGS_LEVEL1;
```

```
            // Set the strings used in the header section of the table
            this.ChartData.Title = "Variable Control Chart (X-Bar & R)";
            this.ChartData.PartNumber = "283501";
            this.ChartData.ChartNumber = "17";
            this.ChartData.PartName = "Transmission Casing Bolt";
            this.ChartData.Operation = "Threading";


            // Display the Sampled value rows of the table
            this.EnableInputStringsDisplay = true;
            // Display the Sampled value rows of the table
            this.EnableCategoryValues = true;
            // Display the Calculated value rows of the table
            this.EnableCalculatedValues = true;
            // Display the total samples per subgroup value row
            this.EnableTotalSamplesValues = true;
            // Display the Notes row of the table
            this.EnableNotes = true;
            // Display the time stamp row of the table
            this.EnableTimeValues = true;

            //     this.PrimaryChart.ProcessVariableData.LineMarkerPlot.LineAttributes.PrimaryColor =
Color.Black;
            //     this.PrimaryChart.ProcessVariableData.LineMarkerPlot.SymbolAttributes.PrimaryColor =
Color.BlueViolet;
            //     this.PrimaryChart.ProcessVariableData.LineMarkerPlot.SymbolAttributes.FillColor =
Color.Beige;
            //  frequency histogram for both charts
            this.PrimaryChart.DisplayFrequencyHistogram = true;
            this.SecondaryChart.DisplayFrequencyHistogram = true;

            SimulateData();

            // Calculate the SPC control limits for both graphs of the current SPC chart (X-Bar R)
            this.AutoCalculateControlLimits();
            // Scale the y-axis of the X-Bar chart to display all data and control limits
            this.AutoScalePrimaryChartYRange();
            // Scale the y-axis of the Range chart to display all data and control limits
            this.AutoScaleSecondaryChartYRange();
            // Rebuild the chart using the current data and settings
            this.RebuildChartUsingCurrentData();
        }


        private void SimulateData()
        {
            for (int i = 0; i < 200; i++)
            {
                ChartCalendar timestamp = (ChartCalendar)startTime.Clone();
                // Use the ChartData sample simulator to make an array of sample data
                DoubleArray samples = this.ChartData.SimulateMeasurementRecord(30, 10);
                // Add the new sample subgroup to the chart
                this.ChartData.AddNewSampleRecord(timestamp, samples);
                // increment simulated time by timeincrementminutes minutes
                startTime.Add(ChartObj.MINUTE, timeincrementminutes);
            }
        }
    }
}
```

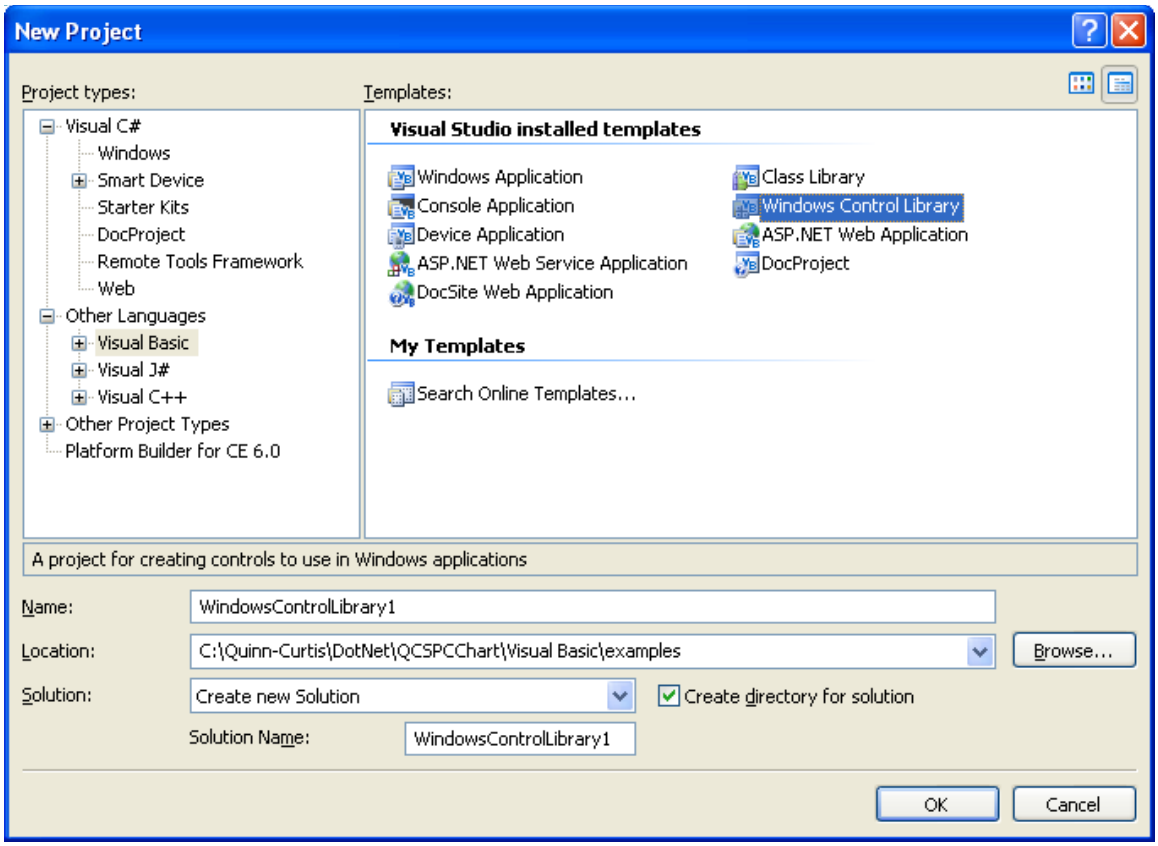
5. Once you can compile the project, copy the resulting WindowsControlLibrary1.DLL file to the desired folder on your web site. In our example we copied the DLL to the http://quinn-curtis.com/UserControlTestRev2/QCSPC folder. The DLL file size should be quite small, since the underlying QCChart2DNet.DLL and QCSPCChartNet.DLL files are not included as part of the WindowsControlLihrary1.DLL. When Internet

Explorer views a web page that properly references the WindowsControlLihrary1.DLL, and its internal **UserControl1** user control, it will download just that DLL. Internet Explorer will not attempt to download the QCChart2DNet.DLL and QCSPCChartNet.DLL files and will look to the system GAC for the DLLs instead.

Visual Basic - Create a Windows Control Library and User Control

You need to create a **ChartView** derived user control that defines your chart, and includes all of the properties that you need for interacting with your chart. This is done almost exactly the same as described in the previous chapter, **Using QCSPCChart for *.Net* to Create Windows Applications.** The difference is that instead of creating a .Net application, resulting in an exe file you can run from Windows, you are instead creating a Windows Control Library, which results in a DLL file. What you end up with is a user control, not an executable program. The user control must be referenced in a specific way in an HTML file before you can display it. The basic steps for creating the **ChartView** derived control are described below.

Start by creating a Windows Control Library project, using the Visual Studio project wizard (**File | New | Project | Visual Basic Projects | Windows Control Library**). On the left select a project type of **Visual Basic Projects**. Give the project a unique name (our version of this example is **WindowsControlLibrary1**). You will end with the shell of a UserControl class with the name UserControl1. You will modify UserControl1 and turn it into an object derived from our ChartView object.



5 Right click on Reference in the Solution Explorer window and select **Add Reference**. Browse to the Quinn-Curtis/DotNet/lib subdirectory and select the **QCChart2DNet.DLL** and **QCSPCChartNet.DLL** files.

5 View the **UserControl1.vb** code. It should look like this.

```
Public Class UserControl1

End Class
```

5 Change the base class of **UserControl1** to **com.quinncurtis.spcchartnet.SPCTimeVariableControlChart** . You do this by changing the base class of the associated **UserControl1.Designer.vb** file. Right click on the "Show All Files" icon (top, second from left of the Solution Explorer). You should see an associated **UserControl1.Designer.vb** file as a node under UserControl1.vb. If so, go into that file and change the base class to **com.quinncurtis.spcchartnet.SPCTimeVariableControlChart**.

```
<Global.Microsoft.VisualBasic.CompilerServices.DesignerGenerated()> _
Partial Class UserControl1
    Inherits com.quinncurtis.spcchartnet.SPCTimeVariableControlChart
```

5 ***Critical Step:*** Make sure you add the following lines to the top of the **UserChartControl1.vb** code to resolve the QCChart2D, QCSPCChart and other graphics classes used in the example.

```
Imports System.Drawing
Imports System.Drawing.Drawing2D
Imports com.quinncurtis.chart2dnet
Imports com.quinncurtis.spcchartnet
```

- Build the Solution (**Build | Build Solution**). This will compile the **UserControl1** class and generate the WindowsControlLibrary1.DLL file. If the project fails to compile you need to go back and check the previous steps.

- You will need to edit the AssemblyInfo.vb file. If you expect to be able to communicate using properties, between your HTML page hosting the control, and the control itself, you must turn on COM compatibility. This is turned off by default in the AssemblyInfo.vb file. Change the ComVisible line to show **true**.

```
<Assembly: ComVisible(True)>
```

- You can add as many custom chart controls as you need for the given HTML page you plan to display charts in. Each custom chart control will inherit from the **com.quinncurtis.spcchartnet.SPCTimeVariableControlChart** control. Or

- (Optional) You can create inherited controls from the **UserChartControl1** class that you already created. Create an inherited control by selecting **Project | Add Inherited Control**. Give the inherited control a unique name, i.e. **UserInheritedControl1**. When you select Open, choose **UserControl1** in the Inheritance Picker. The result is new control added to the project. Build the solution and the **UserInheritedControl1** control will be added to the WindowsControlLibrary1.DLL in addition to the **UserControl1**.

- View the **UserChartControl1.vb** underlying VB code. We placed all of the chart creation code in the **InitializeChart** method. This method is called in the **UserControl1_Load** event, otherwise the **UserControl1** appears as an empty shell. Add whatever properties you need to get data from the HTML file into the chart control (**ChartTitleText** and **EnableInputStrings** in the example below.

```
Imports System.Drawing
Imports System.Drawing.Drawing2D
Imports com.quinncurtis.chart2dnet
Imports com.quinncurtis.spcchartnet

Public Class UserControl1
    Private startTime As New ChartCalendar()
    ' The time increment between adjacent subgroups
    Private timeincrementminutes As Integer = 15

    '''<summary>
    ''' Set/Get the chart title
    '''</summary>
    Public Property ChartTitleText() As String
```

```
        Get
            Return Me.ChartData.Title
        End Get
        Set(ByVal value As String)
            Me.ChartData.Title = value
            Me.RebuildChartUsingCurrentData()
        End Set
    End Property

    '''<summary>
    ''' Set/Get the input string flag
    '''</summary>
    Public Property EnableInputStrings() As Boolean
        Get
            Return Me.EnableInputStringsDisplay
        End Get
        Set(ByVal value As Boolean)
            Me.EnableInputStringsDisplay = value
            Me.RebuildChartUsingCurrentData()
        End Set
    End Property



    Public Sub InitializeChart()
        ' SPC variable control chart type
        Dim charttype As Integer = SPCControlChartData.MEAN_RANGE_CHART
        ' Number of samples per sub group
        Dim numsamplespersubgroup As Integer = 5
        ' Number of datapoints in the view
        Dim numdatapointsinview As Integer = 17


        ' Initialize the SPCTimeVariableControlChart
        Me.InitSPCTimeVariableControlChart(charttype, numsamplespersubgroup, numdatapointsinview,
timeincrementminutes)

        Me.HeaderStringsLevel = SPCControlChartData.HEADER_STRINGS_LEVEL1

        ' Set the strings used in the header section of the table
        Me.ChartData.Title = "Variable Control Chart (X-Bar & R)"
        Me.ChartData.PartNumber = "283501"
        Me.ChartData.ChartNumber = "17"
        Me.ChartData.PartName = "Transmission Casing Bolt"
        Me.ChartData.Operation = "Threading"


        ' Display the Sampled value rows of the table
        Me.EnableInputStringsDisplay = True
        ' Display the Sampled value rows of the table
        Me.EnableCategoryValues = True
        ' Display the Calculated value rows of the table
        Me.EnableCalculatedValues = True
        ' Display the total samples per subgroup value row
        Me.EnableTotalSamplesValues = True
        ' Display the Notes row of the table
        Me.EnableNotes = True
        ' Display the time stamp row of the table
        Me.EnableTimeValues = True

        ' this.PrimaryChart.ProcessVariableData.LineMarkerPlot.LineAttributes.PrimaryColor = Color.Black;
        ' this.PrimaryChart.ProcessVariableData.LineMarkerPlot.SymbolAttributes.PrimaryColor =
Color.BlueViolet;
        ' this.PrimaryChart.ProcessVariableData.LineMarkerPlot.SymbolAttributes.FillColor = Color.Beige;
        ' frequency histogram for both charts
        Me.PrimaryChart.DisplayFrequencyHistogram = True
        Me.SecondaryChart.DisplayFrequencyHistogram = True

        SimulateData()

        ' Calculate the SPC control limits for both graphs of the current SPC chart (X-Bar R)
```

```
        Me.AutoCalculateControlLimits()
        ' Scale the y-axis of the X-Bar chart to display all data and control limits
        Me.AutoScalePrimaryChartYRange()
        ' Scale the y-axis of the Range chart to display all data and control limits
        Me.AutoScaleSecondaryChartYRange()
        ' Rebuild the chart using the current data and settings
        Me.RebuildChartUsingCurrentData()
    End Sub


    Private Sub SimulateData()
        For i As Integer = 0 To 199
            Dim timestamp As ChartCalendar = DirectCast(startTime.Clone(), ChartCalendar)
            ' Use the ChartData sample simulator to make an array of sample data
            Dim samples As DoubleArray = Me.ChartData.SimulateMeasurementRecord(30, 10)
            ' Add the new sample subgroup to the chart
            Me.ChartData.AddNewSampleRecord(timestamp, samples)
            ' increment simulated time by timeincrementminutes minutes
            startTime.Add(ChartObj.MINUTE, timeincrementminutes)
        Next
    End Sub

    Private Sub UserControl1_Load(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles
MyBase.Load
        InitializeChart()
    End Sub
End Class
```

5. Once you can compile the project, copy the resulting WindowsControlLibrary1.DLL file to the desired folder on your web site In our example we copied the DLL to the http://quinn-curtis.com/UserControlTesRev2t/QCSPC folder. The DLL file size should be quite small, since the underlying QCChart2DNet.DLL and QCSPCChartNet.DLL files are not included as part of the WindowsControlLihrary1.DLL. When Internet Explorer views a web page that properly references the WindowsControlLihrary1.DLL, and its internal UserControl1 user control, it will download just that DLL. Internet Explorer will not attempt to download the QCChart2DNet.DLL and QCSPCChartNet.DLL files and will look to the system GAC instead.

Create the HTML File That Displays the User Control

5. Create an HTML file however you normally would do it. You will need to add HTML text to it using some sort of HTML editor. You will find IEQCSPCChart.htm, our example, in the WindowsControlLibrary1 folder. The control is referenced in the HTML file as:

```
<OBJECT id="MyTestUserControl1" height="600" width="800"
classid="http://quinn-curtis.com/UserControlTestRev2/
QCSPC/WindowsControlLibrary1.dll#WindowsControlLibrary1.UserControl1" VIEWASTEXT>
</OBJECT>
```

Notice the *classid* in the <object> tag. The classid has two parts to it. First we have the URL to the DLL file (make sure the DLL is not in the web sites /bin

directory). In this example, the WindowsControlLibrary1.DLL file has been explicitly copied to the http://quinn-curtis.com web site, and placed in the folder UserControlTestRev2\QCSPC. Hence, the URL to the library is:

```
http://quinn-curtis.com/UserControlTestRev2/QCSPC/WindowsControlLibrary1.dll
```

It is then followed by a # sign and ends with the fully qualified name of the control (namespace + control name). In this case that is:

```
WindowsControlLibrary1.UserControl1
```

The full *classid* becomes:

```
classid="http://quinn-curtis.com/
UserControlTestRev2/QCSPC/WindowsControlLibrary1.dll#WindowsControlLibrary1.UserCo
ntrol1"
```

This is sufficient to display the **QCSPCChart** derived user control in a web page using Internet Explorer. If you want to modify elements of the chart you will need to communicate to the control from JavaScript embedded in the HTML page. In our IEQCSPCChart.htm example we added a couple of text fields, one that changes the chart title (text1), and another that changes the y-axis range of the chart (text2). A couple of buttons force the changes to go into affect. Note how the buttons are hooked into the JavaScript event handlers (**ChangeTitle** and **EnableInputStrings**), and how they in turn interact with the properties (**ChartTitleText**, and **EnableInputStrings**) you wrote for the user control. The user control in this HTML file has the id **MyTestUserControl1** and the properties for the user control are accessed using that id. Note that an automatic string to double conversion takes place in the case of the EnableInputStrings property, since EnableInputStrings is a boolean, and text2 is a string.

```
        <script>
            function ChangeTitle() { MyTestUserControl1.ChartTitleText = text1.value; }
            function EnableInputStrings() { MyTestUserControl1.EnableInputStrings = text2.value; }
        </script>
    .
    .
    .
            <P>
            <input type="text" id="text1">    <input type="button" value="Change Title"
onclick="ChangeTitle()" ID="Button1" NAME="Button1"></P>
            <P></P>
            <P>
            <input type="text" id="text2" NAME="text2">  <input type="button"
value="EnableInputStrings" onclick="EnableInputStrings()" ID="Button2" NAME="Button2">
            </P>
```

See the complete HTML file below. It is probably easier to view the IEQCSPCChart.HTM file in the WindowsControlLibary1 project folder.

```
<html>
        <head>
            <meta name="vs_targetSchema" content="http://schemas.microsoft.com/intellisense/ie5">
            <title>Embed a QCSPCChart User Control In Internet Explorer</title>
```

```
            <meta http-equiv="Content-Language" content="de">
            <meta http-equiv="Content-Type" content="text/html; charset=windows-1252">
        </head>
        <script>
            function ChangeTitle() { MyTestUserControl1.ChartTitleText = text1.value; }
            function EnableInputStrings() { MyTestUserControl1.EnableInputStrings = text2.value; }
        </script>
        <body>
            <p><b><font face="Arial" size="4">Hello, this page includes a windows user control!
</font></b></p>
            <OBJECT id="MyTestUserControl1" height="600" width="800"
classid="WindowsControlLibrary1.dll#WindowsControlLibrary1.UserControl1">
            </OBJECT>
            <P>
                <input type="text" id="text1">    <input type="button" value="Change
Title" onclick="ChangeTitle()" ID="Button1" NAME="Button1"></P>
            <P></P>
            <P>
                <input type="text" id="text2" NAME="text2">  <input type="button"
value="EnableInputStrings" onclick="EnableInputStrings()" ID="Button2" NAME="Button2">
            </P>
        </body>
</html>
```

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